Formal Discipline from the Standpoint of Experimental Psychology

A THESIS
PRESENTED TO THE
DEPARTMENT OF PSYCHOLOGY
LELAND STANFORD JUNIOR UNIVERSITY

IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

BY
JOHN EDGAR COOVER

April 8, 1912
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PRINCETON
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PRESS

PREFATORY NOTE

The writer was driven into this problem some years ago through reaction to instruction he was then receiving in education. He owes a debt of gratitude to those men who so faithfully and painstakingly retailed the newest notions culled from heretical theory or hatched from the early and somewhat hasty laboratory work. Interest was more fundamental in school training, in those days, than attention, suggestibility than obedience, and vocational training than mental training. Sherrington's 'spinal dog'[1] had not yet removed by the skillful use of its scratch-reflex, the 'reflex-arc' from the vertebrate nervous system, and it was supposed that we had been endowed with a mechanism by which reactions to stimuli could be literally 'specific'; school training consisted in 'specific discipline,' which was hysterically opposed to 'formal discipline.' Nor had the "All or None" principle of the terrapin heart,[2] yet suggested for mental development the efficacy of strenuous innervation; training needed no spur but interest. Generous acknowledgment of all those incentives is hereby recorded; without them this investigation would not have been made.

The writer is under many other obligations: First and foremost to the Head of the Department of Psychology, Dr. F. Angell, whose courteous extension of laboratory facilities and whose encouragement, advice, and assistance, have put the writer hopelessly in debt; to Professor Lillien J. Martin, for kindly interest and helpful suggestions; to Miss Ruth Adele Sampson for valued assistance in the correction of the manuscript; and to the following groups, almost wholly of fellow-students, who cheerfully and faithfully performed the onerous yet indispensable offices of reagents; those whose names are starred underwent periods of arduous training besides taking the tests:

[1] Sherrington: Integrative action of the nervous system. 1906. Ch. IV.
[2] Stiles: Am. Phys. Ed., 1910, 15: 1-5.

In the experiments on Word-Marking and Weight-Lifting:
*Mr. Geo. Snow-Gibbs.

In the experiment on Discrimination:

*Mr. G. Altnow,
*Mr. T. Nakamura,
*Mr. K. Yasuda,
Miss Bernice C. Rowell,
Miss Bonnye Anderson,
Miss Gertrude B. Weaver.

In the experiment on Reaction with Discrimination and Choice:

*Miss E. Crandall,
*Dr. F. Angell,
*Miss Evelyn Brooks,
Miss Reba Bland,
Miss Rowena C. Bush,
Miss Luella E. Behrens,
Miss Mabel McKibben,
Mr. H. George,
Mr. Geo. Snow-Gibbs.
Miss Mila L. Coffin,
Miss Ruth Cain,
Miss Anita E. Sudden,

In the experiment on Attention:

*Miss Christine Madison,
*Miss Elizabeth F. Lanktree,
*Miss Susan M. Looney,
*Mr. William T. Root,
*Mr. Joel A. Snell,
*Mr. Arthur Heche,
*Dr. F. Angell,
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Mr. Franklin F. Wolff,
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Miss Bertha Van Zwalenburg,
Miss Ray Weaver,
Miss Helen E. Evans,
Miss Edith G. Engelhard,
Miss Maud H. Bassett,
Miss Nina E. Moise,
Mr. Geo. L. Righter,
Mr. Charles L. Allen,
Mr. Asa C. Dimon,
Mr. Roscal L. Draper,
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Mr. Lloyd I. Tilton,
Mr. Alexander Davis,
Mr. Merton J. Price,
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Miss Mabel I. Clark,
Miss M. Dorothy Parkinson,
Miss Nellie Allen,
Miss Mabel B. Angell,
Miss Ruth Hutchinson,
Mr. Harold A. Hughes,
Mr. William H. Bloeser,
Mr. E. Leib,
Mr. Earl T. Dutton,
Mr. Herbert L. Hubbard.

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PART I

ORIENTATION

I. Introduction

The conception of formal discipline[1] belongs to the philosophy of education, and has dominated the educational theory of the greater institutions of higher learning from their inception to the present day. Twenty years ago it was vigorously assailed, however, by some of our eminent educators[2] who claimed that our schools are suffering under the bonds of this tradition. It was charged that the conception is a myth; that the sole end of study is the information acquired by it; that no subject of study is of greater value than another except upon grounds of adjusting the student directly to his social, economic, industrial, environment. It was explained that the 'Dogma' rests upon the 'faculty psychology' which lies respectably buried under the dust

[1] Formal Culture: (formale Bildung; éducation formelle). The doctrine of the applicability of mental power, however gained, to any department of human activity. This doctrine is used as a standing argument for so-called disciplinary education, especially that in pure mathematics and classical languages. The assumption is that if the student masters these, he will thereby acquire a mental power that can be applied almost equally well to any kind of practical or professional life. This gymnastic theory of education involves the idea that it does not matter upon what the mind is exercised, provided only the exercise be rigorous and long-continued.—DeGarmo in Baldwin's "Dictionary of Philosophy and Psychology."

This expression has been used to indicate the general reaction upon the ability of a student that is by many supposed to spring from the method of study rather than from the content which is learned.—Ernest N. Henderson, in "A Cyclopedia of Education," edited by Paul Monroe. N. Y.: Macm. 1911. P. 642.

[2] *Vid.* Hinsdale, B. A.: The dogma of formal discipline. Proc. N. E. A., 1894, p. 625; also his book "Studies in Education," Ch. 2.

DeGarmo: "On the report of the Committee of Ten." Ed. Rev. 1894, 7:277.

Rein: Outlines of Pedagogics (tr. Van Liew) 1895. P. 61.

DeGarmo: Herbart and the Herbatians. P. 26.

of a century, and that its continued vitality is derived from its momentum in a field in which the 'resistance' of modern experimental psychology is wanting. It is true that the challenge was made by men of 'Herbartian' training, that the formal definitions of the conception were made by them and would not be entirely satisfactory to proponents, and that the Herbartian psychology is equally dead.

Nevertheless, the point in dispute has shifted into psychological territory, and it is for this reason that Experimental Psychology has come in contact with the venerable doctrine.

The psychological question at issue concerns the relations which exist between the various mental processes. According to the 'faculty psychology,' the improvement of observation, or of reasoning, or of memory, or of any of the thirty-five faculties of the mind, in one field of experience was applicable to all other fields of experience; but improvement of one 'faculty' did not affect others. According to the Herbartian psychology, these 'faculties' are abstractions, adding nothing to fact and affording no explanation of mental phenomena;[3] the Idea[4] is the sole real content of the mind and through it alone are mental phenomena unified. Training of the mind is effected through the appropriation of ideas and is limited in its applications to the field of experience to which the ideas belong. Both of these psychologies

[3] Herbart's criticism of the 'faculty theory' lies in the two following objections: (1) 'Faculties' are mere possibilities; there is no sensibility before sensation; (2) they are class-concepts, obtained by a provisional abstraction from the inner experience, and then raised to the rank of fundamental forces of the mind and used for the explanation of our internal processes. Both criticisms are as telling against the established sciences of physics and chemistry as against the 'faculty-theory.' (1) The forces of physics do not exist apart by themselves any more than do the 'faculties,' but only in the phenomena called their effects; (2) they are abstracted from the concrete phenomena and are class-concepts used for the explanation of the phenomena themselves. According to the criticism, there is no gravitation before the falling of the apple, nor can it as a class-concept, be used to explain the fall of the apple.

[4] This Idea, as well as its relations to the emotions, feelings, and impulses, is hypothetical and does not at all square with the facts of inner experience. *Vid.* Wundt: Prin. of Phys. Psychology. (From Ger. Ed. 1893.) Pp. 18ff.

have performed their service in the development of the science and are now of but historical interest. The question, therefore, so far as their authority goes, remains open.

Special observation and investigation have sought to throw some light on the problem:

(1) The contribution of formal school training to success or eminence in practical life has been estimated.[5] (2) The relationship between undergraduate scholarship and preëminence in the graduate schools of law and medicine has been reported,[6] and the standing of our Rhodes scholars has been compared with that of their fellows in Oxford who had followed similar (classical) courses but with more rigorous training.[7] (3) Experimental pedagogy has already contributed a large amount of data concerning the relationship between capacities employed in school work or between school subjects.[8] (4) And the data of Cross-

[5] Halleck: Proc. N. E. A., Dep't of Superintendence. 1906. Pp. 34-41.

Pritchett: Fifth annual report of the President and the Treasurer of the Carnegie Foundation for the advancement of teaching. 1910. P. 56.

Dexter: High-Grade Men in College and out. Pop. Sci. Mo., 1903. 62:429.

Schuster: The promise of youth and the performance of manhood, a statistical inquiry. Univ. London. Galton Eugenics Laboratory Memoirs. 1907. III.

Lowell: Appendix to report of the President and the Treasurer of Harvard College. 1908-1909.

Davis: An afternoon view of college life. Stanford Alumnus, 1912, 13:231.

E.g., Cases as extreme as the following can scarcely be ignored: Everyone knows how formal and how unrelated to occidental affairs is the discipline Chinese officials have undergone, yet "it is not on record in Washington that the other foreign legations are in the habit of making allowance for any lack of acumen on the part of the Chinese legation; on the contrary, the Chinese legation is regarded as one of the ablest accredited to this country." F. Angell, in a Commencement Address at Castellejo School, Palo Alto, California, 1911.

[6] Lowell: College studies and the professional schools. Harvard Graduate Mag., 1910, 19:205.

[7] Pritchett: *Ibid.* p. 65.

[8] Catherine Aiken: Methods of mind training. Am. Bk. 1895.

Harper's Mag. Editorial by Charles Dudley Warner. March, 1895.

Winch: Accuracy in school children. Does improvement in numerical accuracy transfer [to accuracy in arithmetical reasoning]? Jr. Ed. Psych., 1910, 1:557.

Education have been found to contribute something toward an understanding of the 'general' nature of voluntary control in its various phases.[9]

It rests, however, with experimental psychology to determine precisely the kind and extent of relationship that exists between the various mental processes, and this task appears to be well begun. There are already at hand some results pertinent to the question to be found scattered throughout the literature; and as a result of direct experimental investigation, the extent and causes of positive and negative influences upon one set of mental processes by reason of training upon another are, within the limits of the respective investigations, revealed. To these results we shall now turn, in the next chapter, before detailing our own experimentation in this laboratory.

Winch: Further work on Numerical accuracy in school children. *Idem.* 2:262.

Starch: Transfer of training in Arithmetical operations. Jr. Ed. Psych., 1911, 2:306.

Wallin: Spelling efficiency in relation to age, grade and sex, and the question of transfer. Ed. Psy. Monograph. Warwick, 1911.

Winch: Transfer of improvement in memory in school children. Br. Jr. Psych., 1908, 2:284; 3:386.

Winch: Some relations between substance memory and productive imagination in school children. *Idem.* 1911, 4:95.

Bagley: Educative process. 1907, Ch. XIII, p. 208.

Ruediger: Indirect improvement of mental function through ideals. Ed. Rev., 1908, 36:364.

[9] Scripture, Smith, and Brown: On the education of muscular control and power. Yale Psych. Studies, 1894, 2:115.

Scripture: Recent investigations at the Yale Laboratory. Psych. Rev., 1898, 6:246.

Scripture: Cross-Education. Pop. Sci. Mo., 1900, 56:589.

Davis: Researches in Cross-education. Yale Psych. Studies, 1898, 6:6; 1900, 8:64.

Woodworth: Accuracy of voluntary movement. Psych. Rev. Mon., No. 13, 1899.

Dresslar: Some influences which affect rapidity of voluntary movements. Am. Jr. Psych., 1892, 4:514.

Raif: Ueber Fingerfertigkeit beim Clavierspiel. Zeits. f. Psychol., 1900, 24:352-5.

II. Evidence From the Literature of Relationship Between Mental Processes

The results of experimentation in the psychological laboratory that have come before the writer's notice and that have a direct bearing upon the question of the kind and extent of relationship between mental processes, are portrayed here in topical fashion, which takes them out of their chronological order, with the hope that the grouping of evidence about the various types of mental activity will prove more satisfactory to the reader. The year of the published results can be seen in the foot-note references.

1. *Habituation to Distraction*

Vogt[10] found that reacting on every stroke of a mentronome decreased the amount of continuous adding 47.7%; that seven days' practice reduced this to 14%; that the effect of distraction upon adding caused by synchronously reciting series of letters was decreased by practicing adding alone; that the adaptation to the distraction of reciting series of letters while adding reduced the distraction of reacting to the stroke of the metronome while learning series of numbers by heart. Among his conclusions are: (1) An adaptation (Gewöhnung) carries over from one special process to another; (2) Becoming habituated to a distraction while exercising one function, habituates to that distraction while exercising other functions.

2. *Sensitivity*

Urbantschitsch[11] sought to determine whether there is a cross-effect (Wechselwirkung) between the senses. "While a uniform excitation was present to one sense a sensation was occasioned through another, from which I perceived accurately during the functioning of the new sense if there were any changes in the sensation of the originally stimulated sense." Listening to a tone lowered the limen for light; it also affected olfactory, gustatory,

[10] Vogt: Ueber Ablenkbarkeit und Gewöhnungsfähigkeit. Psy. Arbeit., 1899-1900, 3:62.

[11] Urbantschitsch: Uber den Einfluss einer Sinneserregung auf die übrigen Sinnesempfindungen. Archiv f. d. ges. Physiologie, 42:154.

tactual, and thermal sensations. "The influence of one sense-excitation upon the sensations from other senses appears clearly to be a valid physiological law."

Epstein[12] set himself to either controvert or support Urbantschitsch's results by more carefully controlling the conditions of the experiment. He sought to find the influence of a sound-sensation upon (a) acuteness of vision, (b) acuteness of color-perception. The observer sat in a dark room and placed his eye to a telescope; the cap was removed and he reported the number of concentric rings on a rotating disc; the second stimulus was given during this fixation and he reported changes in the field of vision occasioned by it. 164 Experiments were made. Upon 60% of the reagents the sound impression increased both acuteness of vision and acuteness of color-perception; upon the other 40% it increased only the former.

Dunlap and Wells[13] gave simultaneously visual and auditory stimuli to four reagents in reaction-time experiments, and found that when the auditory stimulus was reacted to, the reaction time was about 10 sigma longer than to the auditory stimulus alone; if the visual stimulus was reacted to, the reaction-time was about 20 sigma longer than to the auditory alone, but 40 sigma shorter than to the visual alone.

3. *Discrimination*

"Volkmann[14] found that by practice of the left arm in discrimination until an initial ability of 23.6 improved to 11.2, the right arm without any practice showed an improvement from 26.4 to 15.7. Similar results were found for other cases of cross-education and for the spread of improvement in discrimination of touch at certain spots on the skin to neighboring spots."

Bennett[15] trained 16 children (average age 11 years) of the

[12] Epstein: Ueber Modification der Gesichtswahrnemung unter dem Einflusse von gleichseitigen Toneindrücken. Zeits. f. Biol., 1896, 33:28.

[13] Dunlap and Wells: Some experiments with reactions to visual and auditory stimili. Psych. Rev., 1910, 17:319.

[14] Volkmann: Ueber den Einfluss der Uebung auf das Erkennen räumlichen Distanzen. Ber. der Kgl.-Sachs. ges. d. Wiss. (Math. Phys. Col.) 1858, 10:38. Quoted by Thorndike: Educational Psych. (First Ed.) P. 86.

[15] Bennett: Formal Discipline. Teachers College, 1907, (pp. 59ff).

Speyer school in New York City, twice a week from October to March on discrimination of shades of blue, using a Milton-Bradley color-wheel. Judgments were made on whether the inner disc or the outer ring was the deeper blue (greater saturation). The stimuli were thus presented simultaneously. Tests were taken, before and after this training, on discrimination of shades formed by mixtures of (1) red+white, (2) yellow+green, (3) orange+black, and of (4) pitch. For the latter test a Gilbert tone-tester was used, F sharp being taken for the norm. Efficiency was calculated in degrees of change of the sectors, or points of tone-change, corresponding to the range of the judgment "same." The average effect of training was a reduction of this range: Boys 2.7° to 0.8°; girls 4.5° to 0.7°; or boys 65%, girls 80%. The range was reduced in the four tests:

	1	2	3	4
Boys	79%	60%	65%	28%
Girls	84%	57%	56%	23%

Since the First and Final tests were separated by five months, the practice effect of the first test could not have been considerable. Clear transfer is thus shown from improvement in discrimination of shades of blue to shades of other colors, and in a less degree to discrimination of pitch.

4. *Association*

Thorndike and Woodworth[16] trained reagents in estimating areas, weights, and lengths:

Six reagents were trained in estimating areas of rectangles from 10-100 sq. cm. in size, "until a very marked improvement was made." Tests were taken before and after this training on estimating areas of:

a. Same shape and same size
b. " " but 140-200 sq. cm. in size
c. " " " 200-300 " " "
d. Different shape and same size
e. " " " 100-140 sq. cm. in size
f. " " " 140-200 " " "
g. " " " 200-240 " " "
h. " " " 240-over " " "

[16] Thorndike and Woodworth: The influence of improvement in one mental function upon the efficiency of other mental functions. Psych. Rev., 1901, 8:247ff, 384ff.

Efficiency was calculated in amount of average error, and the final results were given in per cent showing the proportion of late to early error. In the whole table of 44 final figures 13 show lack of improvement. And of the 14 totals of the two tables, only one shows lack of improvement. The average results of four reagents (from Table IV, p. 384) show that training reduced error to 48.4% of the initial amount; that improvement was transferred to estimating the other sizes and forms to the following per cents of their original error: a. 39, b. 67, c. 102, d. 62, e. 50, f. 78, g. 86, h. 77; averages for two other reagents, who omitted c. and d., were a. 66, b. 61, e. 61, f. 84, g. 84, h. 76. Counting the complements of these per cents of error as per cent of gain, the gain in the training was 51.6%, the average gain in the tests within the field, same form, was 61%; different form, 38%; above the field, same form, 16%; different form, 51%; for all the tested abilities it was 29%. The extent to which the special practice shows general effect is, therefore, 55%.

Two reagents were trained on a set of seventeen weights ranging from 40-120 grams inclusive, 5-gram intervals, and similar except in weight. Tests were taken before and after training, on estimating (a) 8 common objects averaging 95.8 grams, the weights of which fell within the field of 40-120 grams; (b) 12 common objects averaging 736 grams, the weights of which fell above the field of 40-120 grams. Efficiency was calculated in deviations in grams. W. made in the last test in the training series 51% of the error made in the first test, T. 59.3%. W. showed in the after-training test on objects within the field over 100% of the improvement made in the training series; T. 32%; W. on the objects above the field gained 67%; T. showed no improvement. Averaging the gains of both training and test series, 44.8% improvement was made in the former and 27% in the latter. As a result of the whole experiment the special practice showed general effect to the extent of 60%.

The failure of transfer of improvement to diminish as the material estimated becomes less like the training material should be noted, for its bearing on the proposed explanation for transference through 'identical elements.'

5. *Reaction*

Angell and Moore[17] carried out a long series of experiments with three reagents in reaction-time, in which the responses were made with the hand, the foot, or the lips, to auditory and visual stimuli, in both 'sensorial' and 'motor' forms. Most of the visual series were not begun until after the auditory series (of from 700 to 1500 reactions) had been completed, and they showed a much shorter time than is usual for reaction to visual stimuli; the authors observed that the form of reaction was the same in both groups and that the decrease in time in the latter must be referred to the practice-effect of the former.

Gilbert and Fracker[18] tested three reagents on time of simple reaction, and time of reaction with discrimination, to sound stimuli, light, electrical, and tactual, stimuli; then trained two of them on reaction with discrimination, and one on simple reaction, to sound, for 12 days. Of the 27 records in the re-test with the other stimuli, 25 showed transference of improvement to both simple reaction and reaction with discrimination.

Thorndike and Woodworth[19] trained five reagents in reacting to words, in reading matter, containing both the letters *e* and *s*, by marking out the words. Before and after the training, tests were made in marking out (1) words containing, *i-t, s-p, c-a, e-r,* on similar pages; (2) *a-n, l-o, e-r,* on pages differing from the training material in length of line, size of type, and style of matter; (3) misspelled words and (4) the letter *A* from prepared sheets. Average gain in the training was 38%. In the tests the average per cent of gain was for (1) 21, 22, 10, 14; for (2) 28, 33, 31; for (3) 16; for (4) 10. The transfer of practice-effect was larger for (2) (dissimilar material) than for (1) (similar material). Altogether, the special training showed general effect to the extent of 44%.

[17] Angell and Moore: Reaction time; a study in attention and habit. Psych. Rev., 1896, 3:245.

[18] Gilbert and Fracker: Effect of practice in reaction and discrimination for sound upon the time of reaction and discrimination for other forms of stimuli. Univ. Iowa Studies in Psych., 1897, 1:62.

[19] *Op. cit.*

Carrie W. Liddle[20] sought to determine whether practice in discrimination and sorting of one set of cards bearing colors or geometric signs would assist in discriminating and sorting another set with different colors or signs. Each set of 102 cards contained six colors, or six designs, was shuffled so that no color or device repeated itself, and was sorted into six compartments. The first six cards of the pack determined the order of colors in the compartments according to which the rest of the pack was to be sorted. Nine reagents took part and the experiment continued two semesters. There was transference of practice-effect from one set of colors to the other set of colors, and to the geometric forms; and from one set of geometric forms to the other and to the colors. Increased powers of discrimination and attention were thought to be the causes of transference.

(a) Interference

Some contributions to transference of practice effect point out the fact that the effect is not always positive. It nevertheless indicates functional relationship of processes and is therefore important. Most of the material used in these contributions consists of discriminative reactions, which justifies general treatment in this place.

Jastrow and Cairnes[21] found that when two mental processes, as (1) finger-movements involving rhythm and counting, and (2) adding or reading, are carried on at the same time, the following effects are produced: (a) Simple movements are not interfered with; (b) maximum beating or beating in groups is interfered with: (c) beating in two's and three's (alternately) seriously interferes with reading aloud: (d) the maximum rate of beating hurries the mental process.

Bergström has reported experiments showing interference clearly:

[20] Liddle: Unpublished thesis for the degree of M.L. at the University of California. May, 1904.

[21] Jastrow and Cairnes: Interference of mental processes. Am. Jr. Psych., 1891-2, 4:219.

First.[22] (1) A pack of 80 cards, 10 kinds in each pack, was distributed upon 10 piles. Another pack bearing the same abstract words at the top was distributed immediately after upon re-arranged places; the results of the six reagents showed interference in longer time for the second pack. (2) Cards with pictures of common objects sketched upon them were sorted as before; but with the difference that the time between the packs was varied from 3 to 960 seconds. Series were taken by four reagents for 20 days. Interference was shown for the following intervals (in seconds) between packs: 3, 15, 30, 120, 480; it decreased regularly with the increase of the interval; two-thirds dropped away in the first minute. Time of sorting decreased greatly with daily practice but the amount of the interference did not. In the shorter intervals the reagent was acutely conscious of it; in the longer, not at all. If the interval between the packs is increased to 24 hours, the second pack is sorted in less time; practice effect has overcome interference.

Second.[23] Münsterberg's "Gedächtnisstudien" (Beihefte, Heft 4) suggested the question, "Can a given association function automatically while some effect of a previous and different association with the sense stimulus remains?" Packs of 80 cards, as before, were sorted on ten piles; orders of piles were changed and cards were changed. The answer to the question is affirmative: under certain "simple conditions, interference effect of an association bears a constant relation to the practice effect and is equivalent to it."

Bair[24] performed two experiments in which the practice effect much outweighed interference: (1) "Six keys of a typewriter are labeled with six symbols (letters or figures). Fifty-five of these letters or figures, in chance order, are now shown one by one, and the subject on seeing one taps the corresponding key.

[22] Bergström: Experiments upon physiological memory by means of the interference of associations. Am. Jr. Psych., 1892-3, 5:256.

[23] Bergström: Relation of the interference to the practice effect of an association. Am. Jr. Psych., 1894, 6:433.

[24] Bair: The Practice curve; A study in the formation of habits. Psych. Rev. Mon. Supp., 1902, No. 19.

The time taken to tap out the series is recorded. Six different symbols are then used with a new series composed of them, and the subject's time record is taken as before. This is continued until twenty different sets of symbols have been used. Although the symbols have been changed each time, there is a steady improvement, ranging for the four subjects in the following decrease in time: 62 to 52, 95 to 85, 71.5 to 58, 65 to 56. The major part of this gain could not have been due to merely getting used to the machine or to the general features of the experiments, for the fourth subject was already used to these and still gained about nine-tenths as much as the other three.[25]

"(2) The other experiment consisted in taking daily records, for twenty days, by means of a stop-watch, of the time required

[25] The relation between interference and practice has also been just recently shown by Dr. Warner Brown (Habit interference in card-sorting. Univ. Calif. Pub. in Psychol., 1914, 1:269-321). Fifty-two playing-cards were sorted, according to suit, into a row of four boxes. In the First Series, 26 reagents worked 13 days, sorting 8 packs per day (except on the 3d, 5th, and 7th days when 4 packs were sorted), during the first 8 days with the "original" order of lebels (*D C H S*), during the 9th to the 12th days, inclusive, with a new order each day for the 3d to the 6th packs and the original order for the first and last two packs. Interference in passing from the original order to one of the new orders ranged from 1% to 23%, averaging about 12% (*op. cit.*, p. 294). But in spite of the intrusion of practice in antagonistic reactions, practice on the original order resulted in considerable improvement: The actual amount of improvement from the 8th to the 13th days was considerably greater than from the 4th to the 8th days. The constant interference with practice did not prevent the steady improvement of skill with the original order (p. 307). In the Second Series, 18 students practiced card-sorting (twice a week) for 8 days, according to the same procedure as above except that 24 hours later they took an equal practice on the order *C S D H*. It was ascertained, after the elimination from the two series of all but 14 pairs of scores showing equal initial ability, (1) That antagonistic tendencies were carried over from one order to the other resulting in loss of speed at the beginning of each day's work, (2) that the interference phenomenon was confined to the first few trials of the day's sorting, (3) that it did "not affect the increase of skill in performing the action in the accustomed manner" (313), and (4) that practice on the second order helped in the learning of the first order. From the data of the First Series the author observed that "Four trials of any new order suffice to acquire a speed that it required six days, or 40 trials, to acquire in the original practice (307).

to repeat the alphabet from memory. Each day's experiment was as follows: First, the alphabet was repeated as rapidly as possible forward; second, the letter *n* was interpolated between each of the letters; third, the alphabet was repeated as rapidly as possible backward; and last, the alphabet was repeated backward interpolating *n* between each two of the letters. At the end of twenty practices in each order the subject repeated the alphabet first forward interpolating instead of *n* the letter *x* and repeating three times; secondly, interpolating *r* and repeating three times; then lastly, repeating backward and in like manner interpolating *x* and *r* and repeating three times. There was improvement in the test series, the effect of the twenty days' training with the training series being to put the abilities in the test series as far ahead as three days of the direct training would have done."[26]

He concludes, concerning the first experiment, that "continued practice in one order increases proportionately the ability to make quickly and accurately a new and antagonistic order."[27] And that "any bit of special training helps us to find ourselves. It gives us a method of orientation which leaves us in our reactions not entirely at the mercy of chance even in unfamiliar situations. The experience which we get from special training gives us a general power to meet any entirely new situation with a more favorable response than had we not had this special training.[28]

Louise E. Ordahl,[29] as a result of her work under Sanford's direction at Clark, concludes: "What Bair says in regard to the general ability given by special training, e.g., 'to a new situation we react by a general discriminative reaction and are more likely to hit on a favorable response than without this special training,' is true of all learning. For no matter what new acquisition is undertaken if it is possible to master it, some previous general

[26] Quoted from Thorndike: Educational Psychology (1st Ed.), p. 92.

[27] Psych. Rev., 1903, 10:580.

[28] Bair: Contributions to Phil. Psych. and Ed., Columbia University, 1902, Vol. IX.

[29] Ordahl: Consciousness in relation to learning. Am. Jr. Psych., 1911, 22:158.

training has either been developed by the individual or through the inherited co-ordinations of his ancestors."

McMein and Washburn[30] performed experiments with card-sorting to determine "Whether two relatively complex habits interfered with each other in a less or greater degree than two relatively simple habits." The more complex processes showed less interference.

The relation between interference and practice effect then depends upon the time between practices and the complexity of the processes. The work of Liddle and Blair seems to indicate that improvement can be made in overcoming interference by frequent changes of the associations. This would be a very important general effect of practice.

6. *Memory*

Some of the first work to show transference of practice effect in memorizing was done by Bergström[31] in connection with his investigation of interference in mental activity. He found that upon memorizing four series of non-sense syllables in succession, with but 10 seconds between series, interference was progressive; *i.e.*, each successive series took a longer time to memorize. Similar progressive interference occurred in learning 3 series of 30 digits in succession. This result conforms with that of Ebbinghaus.[32] To determine whether interference under these conditions was caused by recurring materials in re-arrangement, another experiment was performed in which the first series of non-sense syllables were made up of the letters of the first half of the alphabet, and the first series of numbers of the first half of the digits, while the second series were made up of the remaining elements. Since no materials recurred in re-arrangement and the time of the second series was greatly reduced, interference did not take place. Interference was considered an "after-image" of

[30] McMein and Washburn; Effect of mental type on the interference of motor habits. Am. Jr. Psych., 1909, 20:282.

[31] Bergström: Influence of interference upon mental activity. Am. Jr Psych., 1894, 6:267 ff.

[32] Ebbinghaus: Ueber das Gedächtniss, 1885, S. 95.

central activity, and since it occurs with associations formed from impressions from disparate senses, it opposes the dismemberment of memory for facts into different sensory types, where by this distinction it is meant that the same thing can be learned more easily by one sense than by another. The principal fact to note here is that the practice effect of the first series on the second was marked.

Bennett[33] reports transference of improvement in an experiment on memory. Two reagents took part; K. trained 28 consecutive days, learning 16 lines a day of "In Memoriam"; B. trained 35 consecutive days, learning two stanzas of "Faerie Queene" daily. K. was tested on learning a row of 30 digits each day for five days, before and after the training; B. was tested on learning a list of 15 names of places each day for five days, before and after training. K. gained in tests 58% in the reduction of time; B., 22%.

Perhaps the most important investigation of the general effect of special training in memorizing, because of both the length and the rigor of the training, is that of Ebert and Meumann.[34] Although no control experiment was carried along, to determine the effect of the tests upon themselves in the repeated 'cross-sections,' and the quantitative results, therefore, cannot be accepted as conclusive, the amounts of gain shown in the repeated tests appear sufficiently great to create a presumption in favor of the authors' conclusions which seem more fully warranted by the qualitative part of their study.

This research continued from November, 1902, to August, 1903. Six reagents were trained on memorizing non-sense syllables, three taking 64 series, and three 48 series, of 12 syllables each. Usually the work of one day's training consisted in learning two new series and relearning two series that had been learned the preceding day. The number of the days of training for three reagents would thus be 32, and for the other three 24.

[33] Bennett: *op. cit.* (pp. 45 f).

[34] Ebert and Meumann: Ueber einige Grundfragen der Psychologie der Uebungsphänomene in Bereiche des Gedächtnisses. Archiv f. d. ges. Psych. 1904, 4:1.

Before the training, after the six reagents had learned 32 series, after the training, and after a three-month interval of no practice, tests were given. There were thus four 'cross-sections' of memory capacities taken: One for the purpose of determining initial efficiency, two for the purpose of testing the influence upon those capacities of the training on the non-sense syllables, and a final test given after a long interval without practice, to determine the durability of that influence. The tests involved (a) 'immediate memory' or the capacity of reproducing as much as possible of a series of stimuli after a single presentation; and (b) 'complete learning' or the capacity of reproducing a series perfectly after the fewest possible number of presentations. Retention was also tested by relearning after 24 hours the series that had been 'completely learned.' The series for testing both sorts of memorizing consisted of both sense and non-sense material, and were presented auditorially for the tests on 'immediate memory' and visually, by means of a revolving drum, for the tests on 'complete learning.'

The tests and results of the first three cross-sections follow:

Table I. Effect of training on 'immediate memory.'

(a) Number of units correctly reproduced after one presentation.

	Cross-sections			Per cent gain		
	1	2	3	2 over 1	3 over 2	3 over 1
Numbers	7	8.8	11.2	29	26	59
Letters	7.2	9.5	11.3	36	19	58
Non-sense syllables	5.2	6.2	7.3	20	19	42
*Italian words	5	5.5	6.5	10	18	30
*Lines of poetry	15	17	19	13	12	27
*Lines of prose	17	19	22	12	16	29

* Only two reagents.

(b) Number of units reproduced of which a third were errors.

Numbers	10.3	15.8	17.7	56	12	71
Letters	11.2	14.3	16	28	12	43
Non-sense syllables	7.7	11.2	12.2	49	9	59
*Italian words	7.5	11.5	12.5	53	9	67

* Only 2 reagents.

Table II. Effect of training, on (a) 'Complete Learning,' and (b) Retention for 24 hours. Number of Presentations per unit,—per line for poetry and prose.

		Cross-sections			Per cent gain		
		1	2	3	2 over 1	3 over 2	3 over 1
Non-sense syllables	(a)	2.11	.83	.48	61	43	77
	(b)	.49	.27	.20	45	35	59
Optical symbols	(a)	3.83	2.23	.90	42	60	77
	(b)	.68	.35	.30	49	14	56
Italian words	(a)	.273	.175	.108	36	38	60
	(b)	.056	.040	.036	29	10	36
Lines of poetry	(a)	.75	.60	.47	20	22	37
	(b)	.14	.08	.07	43	13	50
Lines of prose	(a)	1.45	.82	.50	43	39	66
	(b)	.30	.10	.09	67	10	70

From the above tables we observe (1) that the total improvement in the untrained 'special memories' compares very favorably with, indeed sometimes exceeds, the improvement in memory for non-sense syllables; (2) that the gain of the 3d over the 2d cross-section compares favorably both with the gains of the 2d over the 1st, and with the improvement made in the second period of training; (3) that the first observation above is applicable to "retention after 24 hours," but that the second is less so; the improvement in retention was not so great for the second period of training (35% as against 45%), and segregation of the scores shows that the group of reagents who took but 16 series in this part of the training is more responsible for the lack of great improvement than is the group who took 32, to the extent of the ratio 19:38 (%'s), and is more responsible for the lack of great improvement in the other tests to the extent of the ratio 8:11. It may be remarked, however, that this group had training equal in extent to that of the other group before the 2d cross-section, and yet in the test on the training material it showed less improvement in retention to the extent of the ratio 28:53 although it showed equal average improvement in retention in the other tests (48%). And it may also be noted that this group made less improvement on Non-sense Syllables in the 2d c-s, and

more than the other group in the 3d c-s, while it equalled the other in average per cent gain on the other tests of both 2d and 3d cross-sections. (4) In connection with the preceding observation it may be noted that although great improvement was shown in the wider capacity of 'immediate memory' (permitting 33% errors—see Table I.b), the second part of the training did not contribute much toward it. (5) Amount of improvement does not seem to depend upon similarity of the test to the training material; *e.g.*, Numbers in Table I. and Optical Symbols in Table II. were more dissimilar to the training material than any of the other non-sense tests, yet improvement in the former exceeds and in the latter equals that shown on the training material; and the gain shown on lines of Prose, in Table II., which differs greatly from the training material in the form of connection between the units of the series, is higher than that shown on lines of Poetry which in the respect noted is more similar to the training material.

The permanence of the improvement in memorizing, as shown by the fourth cross-section,[35] would seem to support the claim that it was not effected by the test practice.

Unless we assume that all the gain on the tests, other than on non-sense syllables, is the result of the practice effect of the preceding tests, we must refer some of the gain in these tests to the training on non-sense syllables; how much, cannot be safely estimated until the tests are repeated, without training, under the same conditions.[36]

[35] Five of the reagents were here given tests on non-sense syllables, and two of them on verses of Poetry, after an interval without practice. This interval was 75, 85, 91, 146, 156, days respectively. There was no decrease in efficiency; some of the reagents showed an increase.

[36] This appears to have been done by Dearborn (Psychol. Bull., 1909, 6:44) whose results "indicate that a considerable part of the improvement found must be attributed to direct practice in the test series, and not to any 'spread' of improvement from the practice series proper." G. E. Müller (Zeits. f. Psychol., 1905, 39:111-125), Wessely (Neue Jahrb. f. Päd., 1905, 8:379-380), Sleight (Br. Jr. Psychol., 1911, 4:390ff), among others, have also criticised the quantitative evidence in the original research. A pupil of Meumann's, however, who took the precaution of performing control experiments, presents, in a Dissertation published from Zürich, evidence that special training

The introspective evidence, as noted above, seems more conclusive than the quantitative. The training effected (1) a change in the whole psychical habit of memorizing, which was applicable to the varied test material: Distaste for the exacting work changed to zest; muscular tensions decreased in intensity and extent; innervation for the work became strong and constant; attention became more economically directed over the parts of the presented material; concentration became more constant; etc. And it effected (2) a change in the method of memorizing: The progress in 'complete learning' became methodical, and learning a series which soon after the beginning of the training was carried on in the various successive stages by definite and distinct motives, as (a) orientating, (b) apperceiving, (c) combining units into a rhythm, (d) anticipating syllables, (e) proving memory, became more of a continuous process in which the various motives were economically combined; the mnenonic aids at first grasped at by all reagents were advantageously discarded, etc. The experience of the reagents thus attests the fact of the general effect of their special practice, and reveals in some manner the cause of this general effect.

Fracker[37] makes another important contribution proving general effect of training when the materials memorized are of a simple nature. A group of four untrained reagents took the tests with the trained reagents, permitting determination of practice effect of the first test upon the second, and the plan and control of the experimentation are excellent.

Eight reagents were given four weeks' training (two or three days a week) in memorizing series of 9 sounds made up of four intensities. These were produced by an electro-magnetic fork and were delivered through a telephone. The four different intensities were produced by switching into the circuit different resistances. Improvement was made by all but one reagent (Fs.).

in memory is also general training in memory. (Radossawljewitsch: Das Fortschreiten des Vergessens mit der Zeit, 1907, S. 182).

[37] Fracker: On the transfer of training in memory. Psych. Rev. Mon. Sup., 1908, No. 38:56-102.

Before and after the training the eight trained and the four untrained reagents took the following memory tests:

1. Poetry (Two stanzas of "Eve of St. Agnes")
2. Order of Four Grays (40 groups)
3. " " Nine Tones (20 groups)
4. " " Nine Grays (20 groups)
5. " " Four Pitches (40 groups)
6. " " Nine Geometrical Figures (5 Trials)
7. " " Nine Numbers (10 series of 9 double numbers)
8. Extent of arm-movement (10 trials for each of 3 standards)

No's 2, 3, 4, 5, were given in "double fatigue order" to equalize fatigue and practice effects upon them.

The relation of the tests to the training series was as follows:

No. 2 different in content, same in method.
No. 3 same in content, different in method.
All others, different in both content and method.

No. 2. A group consisted of 4 grays (No's 2, 7, 30, 45,—Hering) exposed at the rate of one second, remaining exposed one-half a second, with an interval of 4 seconds between the groups. In this interval the reagent responded aloud in numbers 1 to 4, 4 being the darkest gray, reproducing the order of the 2d preceding group.

No. 3. A group consisted of 9 intensities of sound, delivered at the rate of one second, each continuing one-half second. In a nine-second interval between groups the reagent responded aloud in numbers 1 to 4, 4 being the loudest sound, reproducing the order of the preceding series.

No. 4. Same as No. 2, except that 9 grays were given in a group. The reagent responded aloud in numbers, during a nine-second interval between groups, as in No. 3.

No. 5. Same as No. 2 in method, except as to the response, which was made by naming Do, Mi, Sol, Do-2. The stimuli were the notes of the major chord struck upon a piano.

No. 6. The geometric figures were drawn by joining three straight lines (two long, one half-length) so that they joined only at the ends or in the middle, the long lines always adjoined, and formed right angles, none crossing. The nine symbols were

exposed simultaneously for 10 seconds. The reagent responded by drawing the figures, within a time limit of one minute.

No. 7. Nine two-place numbers were read aloud at the rate of one and one-half seconds. The reagent responded by recording within the time limit of 15 seconds.

No. 8. The reagent, with eyes closed, moved his finger with free arm movement along a glass rod from a stationary piece of tubing to one adjusted by the experimenter; he moved his finger out and back twice; then moved it out to the position he estimated to be the same (the adjustable tube being removed); three standards were used.

The tables show that of the 8 trained reagents six made their greatest gains, and the others made large gains, in No. 2, where the material was grays, and the method was the same as in the training on sound; the other two made their greatest gains, and three others made good gains, in No. 3, in which the content was the same as in the training, but the method was different. In No. 4, four made large gains. In No. 5, in which the method was the same as in No. 2, but in which the material was series of pitches, responded to by name, four made large gains. Of the tests which differed widest from the training in material and method, three made large gains in No. 6 (Geometrical figures); three made fair gains in No. 7 (Nine numbers), and one in No. 8 (Movement). In No. 1 (Poetry) four made fair gains.

By grouping the tests in the order of similarity to dissimilarity as compared with the training, and averaging the per cent gain[38] of the trained and of the untrained reagents, we get:

	Similar				Dissimilar			
Tests	2	3	4	5	6	7	8	1
Trained reagents	36%	22	19	10	13%	4	0	7
Untrained reagents	4	11	10	-2	8	0	-1	2
Difference	32	11	9	12	5	4	-1	5

The average gain in training was 21%.

[38] The per cents gain are the differences between the scores which were expressed in per cent of a perfect score; they are not reckoned upon initial efficiency.

And if we average the per cent gain for the respective reagents, we may compare the (a) test gains with the (b) training gains, and the (a) gains of the trained with the (c) gains of the untrained reagents:

Reagents		1	2	3	4	5	6	7	8	9	10	11	12
	(b)	32	25	-9	41	27	29	17	(9)				
	(a)	10	15	6	15	30	15	6	14	(c) 5	8	10	13

The average gain for the trained reagents on the similar tests was 22%, on the dissimilar 6%; for the untrained reagents 6% and 3%. Which indicates that gain in the dissimilar tests was harder to make; that there was greater transfer of improvement in the training to the similar material than to the dissimilar material, and that there was transfer to the dissimilar. The greatest transference to the similar material, however, appears to have been made on No. 2, in which the method and not the content was similar to the training.

But Fracker's emphasis is rightly placed on introspective analysis rather than on quantitative results, and he gives us a good account of the processes involved in the work of his reagents.

The training in memorizing the order of four intensities of sound developed for nearly all the reagents individual systems of visual, visual-auditory, or visual-motor, imagery, involving four steps or four positions by which the sequence of presented intensities was remembered as imaged movement among these positions. These systems of imagery were carried over to the tests involving sequence of four graded units (No's 2, 3, 4, 5) and replaced, for the trained reagents, the changeable and tentative methods employed by all reagents, in the first series of tests. Where the tests were more favorable to the application of this developed imagery, as with the four grays (No. 2), it contributed most effectively to the increase in the score; where conditions did not permit its application *in toto,* as with series of nine units before response (No's 3, 4) and with a series demanding a different form of response (No. 5), there was interference and its efficiency was decreased. Apparently, the dependence upon the system of imagery where interference is great, as in the changed form of

response (No. 5), results in lower scores than were made where the imagery was seen not to apply and reliance was placed upon other and more general effects of practice: more improvement was shown with the simultaneously presented geometric symbols (No. 6) than was made with the pitches (No. 5). Those other effects of training responsible for improvement here, and also in the tests on numbers (No. 7) and poetry (No. 1) appear from the introspection of the reagents to have been (a) systematic grouping of material, (b) freer use of imagery in connection with this grouping, (c) more economic distribution of attention, (d) better concentration of attention, (e) more confidence in power to master the situation, etc. Fracker explicitly states three factors of improvement in training and of transference to the tests, besides the development of these systems of imagery: (a) attention to the essentials, (b) association responsible for building the systems of imagery, (c) automatic use of the imagery where applicable.

It is the chief virtue of this research that it has made clear the importance of individual systems of imagery as factors in the general effect of special practice in memorizing. So far, representative imagery had not been given, in researches connected with the theory of formal discipline, the attention it merits, although its place in mental life is well known.[39]

The ancients, according to Cicero, based their systems of memory training upon spatial position or location, and it is not unusual today for university students to fix points in a lecture in mind by ranging them along the windows and doors of the room.

The psychological laboratory has revealed the prominence of this kind of imagery in the mental organization of not a few re-

[39] The writer desires in this connection to allay the misapprehension on the part of the author (*op. cit.* 98ff.) that his results do not accord with those published by Coover and Angell (Am. Jr. Psych., 1907, 18:327) with respect to the relation between imagery and improvement in practice and between imagery and transference of practice-effect. Representative imagery may be of high value in processes of memory and at the same time be one of the chief distractions in processes of discrimination and of reaction with discrimination and choice.

agents. As an example, Miss Gamble[40] uses systems of representative imagery extensively in memorizing series of stimuli, whether they are odors, colors, or non-sense syllables. The increase in facility in memorizing smells was due to a newly acquired system of associating members of a series with spots on the table-top, which she had previously developed while working with colors. She has worked in smell experiments for eleven years and learns large series of smells with phenomenal facility, yet she has no true smell imagery; her olfactory impressions are replaced primarily by color-images suggested by the materials. With respect to the influence of practice on associations, she says that representative associations remain but that auxiliary associations (as, black-pink, being held by "red eyes of a mourner"; or green-yellow, by "green grass a hunting dog runs over and the corn-meal mush he is fed on";) drop away.

Sleight[41] has recently made a substantial contribution to the question of transference of improvement in memory. He takes his departure from a criticism of the work of Ebert and Meumann, Fracker, and Winch. His objections to the first are (1) too few reagents for statistical treatment of results, (2) no control series to determine the practice-effect of the tests themselves, (3) no evidence that the tests in the various cross-sections were of equal difficulty, (4) inadequacy of the per cent form of statement of results, for one reason because per cents are not equivalent when they are not reckoned upon equivalent stages of practice. His objections to the second are confined to the first of the four just quoted. These criticisms will receive some attention in theoretical discussion later.

His first series of experiments were performed with children of three girls' schools, numbering 21, 28, 35, respectively (average age, 12 yrs. 8 mo.).

Ten different kinds of tests were given to ascertain the memorizing power of each child; these constitute the first 'cross-section,' upon the combined results of which the children of each

[40] Gamble: Study in memorizing various materials by the reconstruction method. Psych. Rev. Mon. Sup., 1909, No. 43:1.

[41] Sleight: Memory and Formal training. Br. Jr. Psych., 1911, 4:386.

school were arranged in order of merit and divided into four approximately equal sections of equal merit; one group was practiced on learning poetry by heart, one on tables, one on prose substance, and one had no practice but spent the time on arithmetical problems or some other task not involving memory work. The practice period lasted six weeks, four days a week, 30 minutes a day. A second cross-section of tests was taken in mid-practice, a third at the close, and a fourth after six months.

In practice (1) the poetry group repeated line by line after the experimenter until the average child could repeat the whole without help. Meter and lines varied. (2) The group on tables learned multiplication, denominations, squares, fractions, etc. (3) The substance-prose group heard read twice selections from scientific, geographical, historical, narrative material, and reproduced the substance of the narratives.

The ten tests were intended to appear to develop out of ordinary school work and were representative of many different processes regularly involved in memory work; they included verbal and logical associations, in couplets and continuous, of letters syllables, and names; spatial associations with one presentation and with several.

Averages were tabulated; and the differences between the averages of cross-sections one and two, two and three, and one and three, for each group of children for each test, were divided by the average of the test standard deviations of the three respective schools. A table of significant values was formed by subtracting the difference-score of the unpracticed group from the difference-scores of the three practiced groups, in each test for the three test-comparisons. Where these values (the difference between the difference-scores of the practiced and unpracticed children) were over three times as large as the probable errors, they were accepted as significant. Since we are limited to a consideration of the 'significant' values, of which there are a few, it is interesting to note that (1) the group trained on poetry showed transfer effect to non-sense syllables and the map test having lost in the test on poetry by an insignificant amount. (2) The group

trained on tables showed transference to points (spatial memory) and to non-sense syllables, having lost on dates by an insignificant amount. (3) The group practiced on prose-substance showed transference to prose-substance and to names. (4) Of the three trained groups only one shows transference to the test most similar in material (Prose-substance) to their training. (5) If the indications of transference are limited to those values which "present really strong evidence" (five times their probable error), but three cases remain: Prose-substance to prose-substance, poetry to non-sense syllables, and tables to non-sense syllables, in the order named, the last being the greatest. (6) The only negative transference occurred from tables to dates, in which arbitrary 'paired' associations were common, but in the latter the sequence of the pairs was disturbed.

The following causes of transference were conjectured: (1) From poetry to non-sense syllables, the common element of rhythm; (2) from tables to non-sense syllables, rhythm and arbitrary associations; from tables to points (spatial memory), visual imagery; (3) from prose-substance to prose-substance, identical material.

Since the results of this experimental series with children were of an unexpected nature and their interpretation had to rest wholly upon statistical analysis, another series was carried out in order that they might be confirmed or contradicted by the new results and introspective analysis.

The second series of experiments were conducted upon two classes of young women (average age, 18-19 years), first-year students, in the Training College (London).

The method and tests were approximately the same as in the first series, except that but six tests constituted a cross-section. The training of three groups of poetry, tables, and prose-substance respectively, continued twelve consecutive days (a Sunday excepted), 30 minutes daily, and differed from the training of the children in that poetry and tables were learned from manuscript instead of from oral repetition. The statistical treatment of the results yields six 'significant' values, and two of these are nega-

tive: (1) The group practiced on poetry showed transference to nonsense syllables and to poetry; (2) the group practiced on tables showed transference to dates; (3) the group practiced on prose-substance showed transference to prose-substance, and negative transference (interference) to non-sense syllables and consonants.

Causes for transference, based largely upon introspective analysis, were presumed to be: (1) From poetry to poetry, identical material and rhythm; from poetry to non-sense syllables, rhythm; (2) from tables to dates, visualization; (3) from prose-substance, to prose-substance, identical material; negative transference to non-sense syllables and to consonants, repugnance for mechanical learning after training on easier logical material.

This second series seems to be quite independent of the first, the significant values of the respective tables of general results agreeing in but one case. The introspections of the adults throw no light upon the results from the children, and fail, in their naïveté, to furnish satisfactory explanations for their own results; they are not to be considered comparable to the introspections of the reagents of Ebert and Meumann, and of Fracker. The results of both series must stand on statistical analysis alone.

In his analysis of results, Sleight finds Thorndike's early law of 'Identical elements' too simple. Cases of transference shown in the above paragraphs do not follow it: (a) The group practiced on tables did not show improvement, but loss, in their 3d test on dates; due to the fact that in the tests they were told the number of repetitions that would be given, whereas in the training they were not, which resulted in a change in the direction of the attention; and (b) the group trained in poetry lost in their third test on poetry, probably for the same reason. Transference to the tests more remotely related to the training material was occasionally large; the greatest transference being to tests on non-sense syllables from training on poetry, and on tables. "The relation which produced transference is not necessarily (a) an external relation perceivable by an observer, nor (b) a relation perceivable by the learner; but (c) a common factor, of which the individual mind makes use, consciously or uncon-

sciously. The individual's awareness of the usable common element may produce an earlier and greater effect." The common element "must be separable from the complexes" in which it occurs. This disintegration resists transference. "The factors which make for transference are similarities of a fundamental nature, such as specific forms of attention, imagery, rhythm; in short, similarities of procedure;"[42] changes in these affect transference more than changes in material.

The general conclusion to which the author is led is that "Specific memory training is specific in its effects."[43]

It appears to the writer that there are apparent reasons which mitigate this conclusion: (1) The unpracticed group was not unpracticed, since these tests involved processes largely exercised in the ordinary work of school. This influence tends to erase the difference between the practiced and the unpracticed groups. (2) There is sufficient indication by significant positive and negative values, of relationship of processes to count against merely specific effect of practice. (3) The assumption that "the mental processes have probably been independent" when the influence of the training is not revealed by "significant" difference-scores, is opposed to the general introspective evidence of other investigators. (4) The criticism of irregularity of results, applied to Winch by the experimenter, seems applicable here, since, as was noticed above, the two tables agree in but one entry.

Miss Gamble[44] in the course of memory investigation with odors, colors, and non-sense syllables, found a great increase in facility in memorizing smells after practice in memorizing colors with which she developed a spatial system of representative imagery. The new system was carried over. And "The results of G. seemed to show that practice gained in the earlier experiments with smells and colors was transfered to the learning of non-sense syllables."

Rall [45] tested two groups of students, upon each of three days, in memorizing poetry (Evangeline) and in memorizing non-sense syllables. One group (44) trained on memorizing for four weeks, 20 minutes a day, individuals choosing various material, such as poetry, prose in English and in foreign languages, irregular verbs and vocabularies in foreign languages. Improvement in training was measured by comparing the last three with the first three days. The second group of 28 took no training.

Results showed wide variations: Of the 44 trained reagents, 4 lost in the training and one lost in the Evangeline tests; 6 out of 34 lost on the non-sense syllables. Of the untrained group, 4 out of 28 lost on Evangeline, 3 out of 16 lost on non-sense syllables. In the training 22 improved more, 20 less, than in the Evangeline test, and 2 improved the same amount; 23 out of 34 improved more (or lost less) and 11 improved less in the training than on the non-sense syllables. The following table gives the average improvement in per cent:

	No.	Training	Evangeline	Non-sense Syllables
Trained	25	32.5	26.9	24.5
Untrained	20		17.8	12.0
Difference			9.1	12.5

In this experiment, then, 25 students gained in training 32.5%, of which 28% was transferred to the poetry test, and 38% to the test on non-sense syllables.

A second investigation was made which agreed with the first in showing the general effect of special practice, but the amount of the transference was smaller.

Radossawljewitsch[46] in conducting experimentation directed by Meumann found that special practice in memorizing improves memory in general.

[45] Rall: Some experimental evidence on the transfer of training in memory. Psych. Bull., 1912, 9:88.

[46] Radossawljewitsch: Das Behalten und Vergessen bei Kindern und Erwachsenen nach experimentellen Untersuchungen. Päd. Mon. Von Meumann. 1907.

Miss Talbot [47] in training her visual memory, not in power but in frequency of use, found general effect in its making memory more sure.

7. *Voluntary Control*

Book [48] found, in his investigation of learning typewriting, that in learning to 'short-circuit' to a higher order of habits, besides habits of manipulation, there were involved 'habits of control.' These with other mental habits "when developed in the sight method of learning, were carried over to the touch method of learning and were used to good effect."

Judd and Cowling [49] report that improvement in drawing an imaged form with the eyes open was transferred to efficiency in drawing with the eyes closed.

Wallin [50] trained two observers in nonocular control of reversions in a number of reversible perspective outlines, such as a book or a pyramid. "Practice consisted in the attempt to uniformly envisage the infrequent or non-predominant perspective." Improvement in 9246 trials, expressed in per cent of successful control, amounted to an average of 42% between the averages of the first and last 20 days (40% and 82%). Tests showed that the improvement was shared by the unpracticed eye. "The effects of practice are central; the training of the one eye established certain cortical tendencies and mental attitudes. The unused retina therefore tended to respond in harmony with the central disposition." Also, earlier in the experiment, reversions occurred about two and one-half times faster in direct vision than in peripheral vision; after practice, reversion occasionally occurred most readily when the figure was in peripheral vision; there was "transference of fixation motives attaching to the fovea to the peripheral retina. . . . The foveal tendency was transmuted into a 'generalized retinal habit.' "

[47] Talbott: Attempt to train the visual memory. Am. Jr. Psych., 1897, 8:414.

[48] Book: Psychology of Skill with special reference to its acquisition in Typewriting. Univ. Mont. Bull., 1908, 53:75.

[49] Judd and Cowling: Studies in perceptual development. Psych. Rev. Mon., 1907, No. 34:349.

[50] Wallin: Doctrine of formal discipline: Two neglected instances of transfer of training. Jr. Ed. Psych., 1910, 1:168.

8. *Summary*

The following summary gives briefly the results of the psychological investigations, coming before the notice of the writer, and reviewed in the preceding pages, which have a direct or indirect bearing upon the question of functional relationship between various mental processes:

(1) Improvement in habituation to distraction is general (Vogt); (2) sensitivity of one sense is increased when impressions from another are simultaneously received (Urbantschitsch, Epstein); (3) reaction-time to one of two simultaneous stimuli is different from the time to either alone, being shorter to a visual stimulus when a sound stimulus is also given than to a visual stimulus alone, and longer to a sound stimulus when both are given than to a sound stimulus alone (Dunlap and Wells); (4) increase in sensible discrimination of two points is shared by surrounding areas (Volkmann); (5) improvement in discrimination of shades of blue (for school children) was transferred to facility in discrimination of shades of other colors, and of pitch (Bennett); (6) improvement in estimating areas, weights, and lengths, was transferred to capacity to estimate areas, weights, and lengths, different from those used in the training (Thorndike and Woodworth); (7) time of simple reaction, and time of reaction with discrimination, to light, electrical, and tactual, stimuli, were reduced through training on simple reaction or reaction with discrimination, to sound stimuli (Gilbert and Fracker); (8) reaction time to visual stimuli was lowered by previous practice in reaction to sound stimuli (Angell and Moore); (9) improvement in marking out words containing each of two given letters, on pages similar to and different from those used in training, and in marking out capital *A's* from a sheet containing 500 capitals, resulted from training in marked out words containing the letters *e* and *s* (Thorndike and Woodworth); (10) there was transfer of practice-effect in sorting cards, from one set of colors to another set of colors, and to geometric forms, and from one set of geometric forms to another, and to the colors (Liddle); (11) functional relationship and interdependence of mental processes are shown by the phenomena of inter-

ference: (a) simultaneous processes may interfere with each other or augment one of them (Jastrow and Cairnes); (b) sorting a pack of cards in re-arranged compartments immediately after sorting another, takes longer time, and in learning rows of non-sense syllables successively, the time becomes progressively longer if they possess recurring elements (Bergström); (c) frequent changes in typewriter-reaction, however, result in capacity to make new and antagonistic series of reaction in less time, and practice in repeating the letters of the alphabet with the interpolation of a given letter between each two, increases capacity to repeat the same series with the interpolation of a different letter (Bair); (d) and there is less interference between complex than between simple processes (McMein and Washburn); (12) training in memorizing poetry improved memory for digits and for names of places (Bennett); (13) memorizing non-sense syllables improved memory for letters, numbers, words, meaningless syllables, Italian words, verses of poetry, lines of philosophic prose, and optical symbols (Ebert and Meumann); (14) memorizing series of sounds improved memory for series of grays, tones, pitches, a square of geometrical figures, and verses of poetry (Fracker); (15) training of memory (for children and students) upon matter similar to schoolwork, resulted in a few significant gains in memory for material similar to, and different from, that used in the training, and deteriorated memory for some similar material (Sleight); (16) memorizing colors gave greater facility in memorizing odors, and practice gained in memorizing odors and colors was transferred to memorizing non-sense syllables (Gamble); (17) memorizing poetry or prose in English or in a foreign language, or irregular verbs or vocabularies, improved memory for poetry and for non-sense syllables (Rall); (18) improvement in voluntary control was carried over from sight to touch typewriting (Book), from drawing with the eyes open to drawing with the eyes closed (Judd and Cowling), from use in connection with one eye to use with the other, and from the foveal to the peripheral vision (Wallin).

An examination of the data reveals the fact that special practice is not wholly general in its effects; is often not largely gen-

eral, but probably is always somewhat general. Under the conditions of the experiments it usually ranges in amount from a fourth to three-fourths of the gain shown in the training.[51]

Of greater importance than the fact of the general effect of 'specific training' however, is the theory that will account for all the facts that have come to notice through the course of investigation and that point to the relationship of all mental processes, but to a relationship that is by no means a simple one. Progress toward such a theory is made by the discussions of investigators, quoted above, who have subjected their numerical and introspective results to a more or less thorough analysis. But since there is, on the surface at least, some conflicting evidence, further work is necessary to unravel the tangled skein of positive and negative relationships, and to account for some apparently anomalous results[52] which occasionally occur.

[51] It is interesting and perhaps significant that the distinction between general and special effects of practice is so generally recognized by the Danes that their language provides separate terms for them (Faerdighed, general; Udenadlaeren, special). *vid.* Meumann: Beiträge zur Psychologie des Zeitsinns. Phil. Stud., 1893, 8:435.

[52] Of which further notice is taken on pp. 64ff.

PART II

EXPERIMENTAL

I. PRINCIPALLY QUANTITATIVE

The following four experiments (performed 1903-5) took their departure from the work of Thorndike and Woodworth.[1] The amount of transference was still in question, and the theory was still that of "identical elements" of a relatively simple nature, largely motor. Although the principal contribution is quantitative, the analysis of processes is not neglected—all experiments were accompanied by introspections.

1. Experiments on the More Complex Processes

In order that we could start on an even footing with the investigation referred to, it was necessary to repeat some of the experiments; the following two were chosen: a. Marking out words containing two given letters, and b. Estimating weights.

a. Marking Out Words

Two reagents were trained for 11 days in marking out words containing *e* and *s* in selected columns of the "Outlook" Magazine. Each reagent looked over 12,000 words in each day's practice.

Tests were taken before and after training, in marking out

(1) Words in "Outlook" columns containing *e-s, i-t, s-p, c-a, e-r*.

(2) Words on manuscript pages containing *a-n, l-o, e-r*.

(3) Common nouns in "Outlook" columns.

(4) Words in "Outlook" columns containing *e-s*.

The manuscript pages were prepared with a script 'type-wheel'

[1] *op. cit.*

on a Blickensderfer typewriter and were typed in purple ink. They differed from the printed columns in (a) length of line; (b) color, (c) size, (d) form of letters; (e) letter-spacing; (f) line spacing. This provision was made in order that we might determine if marking out words consisted simply of reactions to visual symbols. If so, then training the *e-s* function on printed matter would show much less effect upon the functions employed on the manuscript pages than on the printed columns. And if improvement in the trained function consisted to an appreciable degree in eye-movements or other habituation to the printed material, there would also be less improvement carried over to the functions employed on the manuscript pages.

The results in time and accuracy are given in Table I (Appendix A, p. 259) and also in per cents in Table II (p. 260). From Table I are drawn the two curves on Plates I and II (p. 261) which show in absolute amounts the acquired efficiency (in speed) in the *e-s* function, and the amount efficiency in the other functions was increased thereby, for the two reagents.

From Table II are drawn the curves on Plates III and IV (p. 261) which show the per cent of acquired efficiency in the trained *e-s* function and the per cent of improvement made in the tested abilities of other functions.

Plate VII (p. 262) shows the course of efficiency with *e-s* words during training.

Calculating gain by finding the complement of the per cent of time, the two reagents gained in the training series 57% and 31%, in the test series on "Outlook" columns 50% and 20%, on the manuscript pages 30% and 30%; on nouns 14% and 6%, and on all 42% and 24%. The special practice shows general effect, therefore, to the extent of 74% and 77%. That the improvement in the final tests is not due to the practice-effect of the first tests may be learned from Table I, in which are shown the results on *e-s* words with which the first test began and ended; For Gs. this effect was 12% , for Cr., −3%.

The accuracy is quite uniform for the tests, although in the training considerable improvement was made. (Table II, Plates V and VI, pp. 260, 262.)

Our results in comparison with those of Thorndike and Woodworth are given in the following table. They show about the same improvement in training, but more general practice-effect. 75% instead of 49%.

Table Comparing Data
Per cent Improvement

	Reagents	In Training	In Tests On Similar Data	In Tests On Dissimilar Data	Avg.	Extent of general Practice-effect in %
Thorndike	Ber.	19	12.5	4	10	53
and Wood-	Br.	51	21	35	19	37
worth's	Be.	37.5	16.5	30.3	21	57
Reagents	Wh.	44	5	25	10	23
	EMT.	36	24	33	25	69
Our	Gs.	57	50	30	42	74
Reagents	Cr.	31	20	30	24	77

(The per cents are reckoned on the time of the first tests; in last column, on the amount of improvement in the training.)

The table shows more improvement in tests on the dissimilar data than on the similar data, by 4 reagents in Thorndike and Woodworth's experiment, and by one in ours.

(1) *Conclusion*

Our results seem to indicate that habituation to the training data was not a great factor in transference of the practice-effect. Some slight improvement may have been due to habituation of eye-movement and eye-adjustment to the word-hunting process, to facility in pen-manipulation and to the dropping away of gross motor accompaniments of mental effort.[2] A little may have been due to learning a method of looking for words; as, keeping more prominent in mind an image of the least frequent letter and using it as a cue. *But the transferred improvement seemed principally due to reducing the recognition of a word as containing given letters to its essential process.* Introspections note the ease and automatism of the process in the after-training tests:

[2] Lindley (Am. Jr. Psych., 7:491ff) finds a considerable list and points out that some of them are detrimental.

Cr. remarked, after test on *c-a,* "seemed almost as easy as *e-s,* though the words as recognized were not of that familiar cast which some *e-s* words had acquired." Gs. remarked, after test on *e-r,* "Seemed to me as if I were marking almost as mechanically as I had done the *e-s.*" Gs. remarked, after test on *a-n* words in manuscript, "marked with great facility of recognition and very mechanically." *The process of recognizing words as containing given letters had been relieved of the unnecessary and retarding accompaniments (kinaesthetic, motor, and acoustic images)* noticed in the introspections of the first tests and in the early training.

These retarding accompaniments consisted in (a) repeating over and over again, in inner speech, the names of one or both of the letters sought, or their sounds[3]; and in (b) repeating the separate words, or actually reading the text, in order to determine whether the words contained the sounds which were held in mind as auditory images. Even when the method was adopted to recognize by visual images, these were strongly supported by kinaesthetic-auditory imagery; which indicated that the most difficult feature of the exercise lay in recognizing words as containing the critical letters.

Training reduced this process to an almost automatic visual-motor act, and greatly reduced the time of a given performance. There was no kinaesthetic or auditory tendency in the process, in the final tests, except where the process was felt to be specially difficult (Gs. could scarcely distinguish the *a's* from the *o's* in the manuscript, and consequently had a tendency to pronounce the sound of *a* at times; Cr. had some difficulty in recognizing *i-t* in the printed columns). This chief factor of improvement in the training is identical with the factor of improvement in the tests.

The processes for both reagents, in the different experiments in the first test, were various: (1) reading, (2) kinaesthetic-auditory cue of letter-names, (3) of letter-sounds, (4) visual

[3] Secor (Am. Jr. Psych., 11:236) found auditory and articulatory factors to be aids, especially with difficult material, but not necessary elements in visual reading.

image cue of letter forms, (5) imagery of the one letter only as the cue, (6) lines, or words as units for search, (7) mechanically searching for projections of letters, etc., sometimes varying within the single experiment, but usually playing the dominant role throughout an experiment.

In the final tests the process was almost uniform, for each reagent, throughout the different experiments. That this change was not merely a change in method, is indicated by the fact that it took five days of training (12,000 words per day) to get rid of the retarding accompaniments of the recognition process. (See practice curve in Plate VII, p. 262.)

Some special factors were noticed in the training which would not contribute to general effect: certain common words often recurring were reacted to by the word-marking impulse without engaging the word-inspecting process; and the familiarity of the images of the capital forms of the letters rendered capitalized words easily recognizable.

In the first test Gs., in marking out *s-p* words, took *p* for the cue and ran his eye along under the line for the projecting stem; and *l-o* words in the manuscript, above the line for the loop of the *l*. In the final tests, although *p* and *l* were the visual cues, respectively, the words were searched for the complete letters. (This accounts for the smaller gain on *s-p* and *l-o* words as shown by the tables and charts, in the Appendix A, pp. 259ff.) Cr. used the same trick with *s-p* words in the first test, but not in the final, which yielded him also a very small score—about half of the score for the *e-r* words.

The observation that marking out words containing different pairs of letters engages essentially different processes cannot be taken as a criticism of the claim that the main factor of improvement is also a factor of transference. Marking *e-s* words is not a simple but a various process, even with a single reagent. It does not only change as a result of training, but at any one sitting it varies with words of different length and of different distribution of the critical letters. These variations may be so regular as to show in a large amount of marking (by a given reagent), various constant errors. *E.g.*, Gs., in his training on *e-s* words, omit-

ted a much greater proportion of 6-letter words than any others, and of words in which *e* and *s* were separated by three or four letters than any others, of words also containing *x* than of those also containing *ch, є, ç, or z.* Cr., in his training on e-s words, omitted a much greater proportion of 4-letter words than any others; of words in which *e* and *s* were separated by four letters than any others; of words also containing *z* than also containing *ch, є, ç,* or *x.* Gs. recognized *e-s* words principally through kinaesthetic or sound image of *s, x* was his great distraction, and half the words he marked in error contained *є* interpreted as *ç.* Cr. recognized *e-s* words principally through their visual images, using *s* as a cue, and *z* was his great distraction.

Although the process varies not only with various words and with various reagents, general effect of the special practice is shown quantitatively by the tables and qualitatively by the introspections, to be the rule for both similar and dissimilar data. And we take the principal factor of improvement to be essentially general in nature.

b. Estimating Weights

Two reagents were trained for 14 days on a set of 17 Chicago suggestion blocks ranging from 40-120 grams, all similar except in weight. Each reagent took 100 series, making 1700 judgments. (See Tables V and VI for data of the first and last series, pp. 263-4.)

Tests were taken before and after training on estimating (a) Ten common objects, averaging 67.5 grams in weight, and all falling within the 40-120 gram field; and (b) Ten common objects, averaging 552.7 grams, and all falling above the 40-120 gram field. (Detailed results are given in Tables VII to X, pp. 264ff; averages, in Tables III and IV, pp. 260, 263.)

All weights were lifted from a cushioned surface through a distance (about six inches) limited by a taught cord, during a given time (one-half second) controlled by a metronome, and were replaced in the same time,

Efficiency was measured in per cent—the ratio of the amount of deviations in the final to the first tests. The following table gives the averages for each reagent:

Reagents	Training Series 40-120 g.	Test Within Field 40-120 g.	Test Above Field
Gs.	74	71.6	56.7
Cr.	80	70.8	244

If per cent of improvement is found by taking the complements of the per cent of error, we get the following comparison of averages with the results of Thorndike and Woodworth:

Reagents		Training Series 40-120 g.	Test Within Field	Test Above Field
Thorndike & Woodworth's Reagents	W.	49	62	33.2
	T.	40.7	13	-1.2
Our Reagents	Gs........	26	28.4	43.3
	Cr.	20	29.2	-244

From the tables it is noticeable that our results are more uniform for the two reagents than are those of Thorndike and Woodworth's. In each case one reagent shows no improvement in the tests on objects above the field, Cr. making 244% more deviation in his final than in his first test. With this exception our reagents showed in the test series more improvement in every case than was made in the training, and thus show more general practice-effect than was shown in the original experiment.

Cr.'s loss of 244% in the test on objects above the field is easily explained by his introspection that his estimates "were mere calculations upon the old reproduced kinaesthetic image of the 1000-gram scale weight" which was accidentally handled just before the first test was taken, and by the fact that his deviations in the first test were remarkably small, totaling only 15% of the total weight lifted; (his deviation on objects inside the field in the first test was 26.1% of the total weight lifted; the corresponding figures for Gs. were, inside the field 29.7%, outside the field 52.8%). (Besides the tables referred to, see also Plates VIII to XII, pp. 266ff for curves.)

(1) *Conclusion*

The process during the training in Cr.'s case was a building up of a definite idea of the 40-120 gram field, and of acquiring facility in estimating the relative position of any weight within that field; in the case of Gs., a deepening of the impressions of the 40-gram and 120-gram blocks, which were used as bases of judgment. No hard and fast associations between the "heft" of a weight and the idea or expression of its weight in grams could be detected.

No definite associations were built up for probably two reasons: (1) Each series consisted of 17 blocks, which number was probably too great to permit identity[4]; and (2) the "heft" member of the association is exceedingly variable, for besides the influence of the preceding weight, of the preceding estimate, and of the preceding error, it was affected by (1) the height at which the weight is grasped with the fingers, for if it is grasped at the top the block will "swing" and if it is grasped at the bottom it will "topple," in either case being "active" in comparison to the equilibrium of the grasp at the center of gravity, it is likely to be over-estimated; (2) the tightness with which it is grasped, for a loose grasp (a) permits a "pull" on the skin of the finger and thumb, tending to cause over-estimation, and (b) does not permit "coldness" of the weight to be so well sensed, tending to cause under-estimation; (3) whether or not the reagent has been holding his pen tightly in writing introspections; (4) whether the hand is cold or warm, upon which depends the seeming temperature of the block, a cold block appearing heavier than a temperate one; (5) whether the weight is lifted with a jerk, which increases its "heft"; (6) whether it is stopped with a jerk before setting it down, which also increases its "heft"; (7) whether reagent is in "good tone," else all weights seem heavier; (8) and whether one's attention is distracted by counting metronome beats by which to gauge the movement.

This process of estimating weights is therefore a very complex one, and for that reason not best fitted to throw light upon our

[4] That recognition of stimuli diminishes with increase of members in the series, was shown by Lehmann (Ueber Wiedererkennen. Phil. Stud., 5:138).

problem, too many irrelevant factors are possible in both training and tests, to leave our results unambiguous. Witness the fact that more improvement was made in the test than in the training series.

Both of the activities engaged in these two repeated experiments were rather complex, and both included motor elements that come in for their share of the general effect of special practice. These experiments had been devised to learn the relationship of activities with reference to the product of their application rather than to their kind,—they were word-marking and weight-estimating activities among which we have found general practice effect, and have determined the principal factors to be general in nature.

An ideal experiment for determining functional relationship of mental activities, it would seem, should be devised with reference to some well-known and simpler kind of mental activity, with conditions such that identical motor elements do not share responsibility with mental factors for general effect of practice.

2. Experiments on the More Simple Processes

The following two experiments[5] were devised to meet the requirements just mentioned. They employ the same kind activity upon dissimilar stimuli and engage different motor elements. Any transference here of acquired efficiency from a trained to an untrained mental activity must be explained upon psychical grounds alone.

The first experiment was devised to determine the effect of practice upon efficiency in an unpracticed activity; the second, to determine the effect of practice upon facility of improvement in another practiced activity.

a. Sensible Discrimination.

Four reagents were trained in Sensible Discrimination of the intensities of *sound* for 17 days during an interval of 57 days. Each reagent took 40 judgments per day's training.

[5] A brief report of these was made by Coover and Angell in the Am. Jr. Psych., 1907, 18:327, under the title of "General Practice Effect of Special Exercise."

Before and after training they were tested in sensible discrimination of intensities of *brightness,* each test consisting of 3 days' tests of 35 judgments each.

In the training on sound the stimuli were given with a Wundtian sound-pendulum.[6] The method was that of constant changes, Right and Wrong Cases, procedure without knowledge. The variable succeeded the norm in 4 seconds. Some $D = 0$, many $D \gtrless S$ and the larger $D > S$. The number of $V > N = V < N$, and there were about ten values for D in each series. Judgments were made in four categories: $>$, $<$, $|||$, and ? (greater, less, like, and undecided). In a couple of series each day introspections were noted down by the reagent after each judgment; in the remaining series noting introspections was reserved until after each series. Reagents sat in marked positions with backs to the apparatus. This training consisted of very careful work, the data being designed for use in another investigation also.

Efficiencies at the beginning and the end of the training were calculated in per cents of Right cases in the first ten and last ten judgments made upon six values of D. Judgments on $D=0$ were not included, and 'like' judgments on other values for D were counted an 'undecided.'[7]

Table XIV (p. 270) gives the number of R, W, and U judgments, per cent of R judgments made on each variable, and the per cent of R and U judgments made in each series, at the beginning, and Table XV, at the end of the training on sound.

In the tests on brightness a Marbe color-mixer[8] was used to present the stimuli. Artificial light was used, and the apparatus, including the disc when not exposed, was securely screened in black. Apparatus was also mounted on noiseless bearings. Values for D were chosen after a preliminary series so that there would be some $D>S=V>N$, and some $D>S=V<N$; some $D \gtrless S$ and some $D=0$. The variables succeeded the norms in

[6] Ill. in double form in Wundt: Grungzüge d. Physiol. Psych. (5th Auf.), III:503.

[7] Cf., F. Angell: Discrimination of shades of gray, etc. Phil. Stud. 19:20.

[8] Illustrated in Wundt: Grundzüge d. Physiol. Psych. (5th Auf.), I:524.

4 seconds and the disc was exhibited 2 seconds. As in the training in sound, a signal was given two seconds before the norm was given. The method was that of Right and Wrong cases, and the procedure was without knowledge. Judgments were given here also in the four categories. Introspections were noted by the reagents after each series of 7 judgments. Each day's experimentation was preceded by a short preliminary series, the judgments of which were not recorded. The order of variables which was used in the before-training test was repeated in the after-training test, and was believed by the reagents to be by chance.

The initial efficiency of the reagents in brightness-discrimination was calculated in per cent of R judgments. Here also the judgments on D=0 were not included, and the 'like' judgments on the other values of D were counted as 'undecided.'

Tables XI-XIII, pp. 269ff, give the number of R, W, U judgments made in brightness-discrimination for each day, number of R, W, U and % of R judgments for each test, upon each variable; and totals for each test, both before and after training.

(1) *Control Experiment*

In order to be more sure of the factors of transference, in case there should be any, a control experiment was devised.

Three reagents were given tests in brightness-discrimination under conditions identical with those obtaining with the regular reagents, except that two instead of three days were taken as a basis for a test. And after an interval, without practice, of 46 days, the tests were repeated.

Tables XVI-XVII (p. 271) give the data from which efficiencies were calculated in the same manner as were the others.

Tables XVIII and XIX (p. 272) compare the results of the two groups of reagents.

(2) *Results*

A comparison of results for all reagents is given in absolute amounts in Table XVIII and in relative amounts in Table XIX.

The per cents in the latter table are all reckoned upon the whole number of judgments in their respective tests which are represented in the tables.

From Table XVIII it may be seen that in the test on brightness-discrimination Aw., a regular reagent, made 66.7% in R judgments before training, and 71.1% after, showing a gain of the difference, 4.4%. He made at the beginning of training on sound-discrimination, 36.7%, and at the end, 51.7%, showing a gain resulting from training of the difference, 15%. In both test and training series he lost in 'undecided' judgments.

Rl., a control reagent, made in the test before the unpracticed interval 68.3% in R judgments, and 63.3% after, showing a loss of the difference, 5%. There was also a gain of 5% in 'undecided' judgments.

Of the four regular reagents, Ya. is the only one who did not show improvement in the test in brightness-discrimination, and he shows no improvement in training on sound-discrimination. He is the only reagent, also, who shows an increase in U judgments in the test series, and he shows similar increase in the training series.

All control reagents show a loss in R judgments[9] in the test

[9] To a statement of this fact in a former report (Am. Jr. Psychol. 18:332) a recent reviewer objects: "But the only use to which this fact should be put is to prove the unreliability of a determination of discrimination of brightness based on seventy comparisons of pairs of grays. To defend general spread of special practice by the doctrine that men possess a tendency to grow worse and worse each week if left without it, is more damaging to it than to attack it." (Thorndike: Educational Psychology, vol. II, p. 400.) This "only use to which this fact should be put," it must be confessed, did not appear so conclusive to the authors of that report in the face of the consistency of the three measurements; they were inclined to let it stand as evidence of *no improvement*. Since some further significance, however, seems demanded, the writer begs to suggest that owing to general fatigue of the reagents, incident to the heavier work of the end of the Semester, or to slightly more difficult conditions for discrimination, incident to the use of another pair of discs in all the after-interval tests, either or both limiting causes applying equally to both groups of reagents, Right judgments were slightly more difficult to make after the interval than before, and, consequently, the real effect of practice in sound-discrimination upon facility in brightness-discrimination is probably *in excess of the amounts reported in the tables.*

An implication, in the same review, to the effect that the use of 'like'

after their unpracticed interval, and two of them show also a gain in U judgments.

(3) *Conclusion*

The transference of improvement in sensible discrimination from training on sound stimuli to efficiency with brightness stimuli would seem to be unequivocally shown by these results.

All the reagents who showed improvement in the training on sound, showed improvement in the tests on brightness. One reagent who took training and did not show improvement in the tests on brightness showed no improvement in his training on sound. All the reagents who took the tests on brightness, but who took no training during the interval between the tests, showed no improvement.

The increase in efficiency in brightness discrimination was not due to practice incident to the tests.

The factors of improvement which have proven to be so general in character are not identical motor elements, for application to the two kinds of data employed disparate senses.

To locate them we will have to resort to an analysis of the

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judgments has clouded our measurement of the capacity for discrimination and has opened the door to increase in Right judgments merely through "taking pains to get a judgment of difference one way or the other" (p. 400), neglects several important considerations. (1) There is no psychological procedure, with the method of Right and Wrong Cases, for determining the capacity for sensible discrimination without the use of the 'like' or 'undecided' judgments; (2) The process of discrimination is itself "taking pains to get a judgment of difference one way or the other," and increase in capacity involves diminishing the number of U judgments in the increase of the number of R judgments. (3) If "taking pains" were to involve *guessing* and not judgment of difference, W cases would increase as rapidly (theoretically) as R cases in the reduction of the number of U cases; whereas, the two trained reagents (Aw. and Cr.) who increased their R cases most also decreased slightly their W cases. (4) A forcing of judgment "of difference one way or the other" would adulterate the R cases, won by "taking pains," with R cases, won by chance, distributed by the usual caprice of variability from theoretical probability, and, consequently, would preclude a measurement of the capacity for discrimination altogether. (5) The use of 'like' or 'undecided' judgments permits the segregation of guesses from judgments, and, consequently, the measurement of capacity for discrimination in per cent of R cases.

process of discrimination which the introspections from the training in sound enable us to make.

Although sensible discrimination is one of the simplest and most fundamental of mental activities, these introspections show it to be quite complex: The attention during discrimination may have an

(A) External reference, in which case the events compared are thought of as external to the body. And the judgment may be the result of (1) Comparing images, or it may be (2) Absolute (without comparison). If it is the result of

(1) Comparison of images, the essential or sound images may be accompanied by images of disparate senses which may control the judgment; they may be

(a) Kinaesthetic, as pronouncing the name of the quality or intensity of sound, or as the feeling of effort necessary to produce the sound, by striking the table with a gavel (Aw. May 5, IV); or

(b) Visual, as picturing the apparatus and the falling ball, as seeing one strike a table with a gavel, as seeing a ball fall, as seeing smoke that would be produced by a percussion cap sounding that loud, as seeing a phonetic illustration of the sound; e.g., "Visual image of a tool bench where I worked a while last summer; the sounds seemed similar" (Aw. May 8, IV). Had a visual image of "an object falling on sounding board" (Aw. May 5, IV). Had a visual image of a "mouth slowly contracting to give a lower sound" (Aw. May 5, IV). "Had a sudden visual image of illustration in phonetics to fit the norm, and thought of it as about three and one-half inches in diameter the short way. When the variable came it took like form, but smaller." (Cr. May 10, II).

(c) The sound images may come with attributes of quickness, sharpness, length, breadth, or distance: "Variable came forth quickly. Had visual image of quick movement" (Na. March 15, II). "Variable had a long-drawn-out sound" (Aw. May 8, II). "Variable is broader sound, that is to say, widely spread" (Na. March 13, II). "Variable comes from farther place," "Variable comes from nearer source," "Variable is a small sound" (Na. March 13, II).

(d) The accompanying imagery may be auditory, as, "Pitch was higher," (Cl. March 15, I). "Lower in pitch" (Cl. March 15, I), or it may seem muffled. Then there are

(2) Absolute judgments made without comparison, and which may or may not be accompanied by the same imagery as the above. "The last one was weak, and I did not compare it with the norm" (Aw. March 13, I). And the final form is

(3) Without localization of the sounds and without accompanying images from disparate senses.

But the attention during discrimination may have an

(B) Internal reference, in which the events compared are thought of as internal to the body. The comparison of norm and variable may be between

(1) Ear disturbances, the ringing or resonance of the sounds as located in the ear. "Had resonance in ear" (Cl. March 13, II). Or comparison may be between the

(2) 'Affects' upon us as a sensing being, and may be accompanied by imagery, as of being struck on the arm with the suggested intensity. "Discriminate 'affects' in head rather than external sounds" (Cr. May 15, IV). Or the comparison may be between

(3) Degrees of reaction to the two sounds, in which the reagent abstracts from the kind of stimuli,—light, tactual, or electrical, would do as well and could be compared with each other,—as the reactions to a flash from a search-light or the explosion of a torpedo; to the flash of a bicycle-lamp and the slam of a door or a nudge in the ribs. "Seemed to compare reactions to the sounds" (Cr. March 15, I and March 20, III).

This classification of factors involved in the process of sensible discrimination of sound stimuli, as the introspections quoted will serve to indicate, is not merely a logical scheme, but rests solely upon our results. These are some of the factors involved, and they may become controlling factors also, so that had they not accompanied the process, the judgment upon a given pair of stimuli would have been reversed. Without doubt the imagery, whether attention is directed externally or internally to the events compared, is in its quantitative aspect suggested by the real intensities of the sounds. But the imagery may carry the suggesting elements beyond the degree suggested; and it may, if it is not suggested by the intensity but by some other attribute of the sound, counteract and overcome the real relation of the intensities, so as to reverse the judgment. E.g., (1) If the imagery is that of falling balls upon a sounding board, and some quality of the given sound other than intensity suggests the second as being larger than the first although it does not appear to fall from as great a height (suggested by the intensity of the sound), the judgment may be 'greater' in deference to the suggested difference in size; when, had the imagery left the size the same, the judgment would have been 'less' in deference to the height. (2) If the second sound seems to come from farther away than the first, judgment may make allowance for the difference in distance and thereby underestimate the former. Or (3) if the second sound seems muffled, allowance

may be made in the judgment for it and it may be reported as intense as it would have been had it not been muffled. (4) If the second sound seems quicker, sharper, or narrower, its intensity through analogy from pressure or pain sensation may be overestimated. (5) When the ear disturbance is the object of attention, the variation of the pressure of the air in the middle ear due to the eustachian tube opening and closing while swallowing, and of the adjustment of the tympanum, make different bases upon which sounds of the same intensity may be judged to be different. (6) If the 'affect' is the object of attention and the imagery is of being struck, any suggestion that results in having the second stroke fall upon the same or a more tender place might lead to over-estimating its intensity. (7) And our reactions may also be modified by elements of imagery suggested beyond the warrant of the intensities of the sounds, and also by an imagery in which our responsiveness is an essential element, so as to result in modified judgments upon the sounds (reactions).

Besides these various factors which accompany the essential sound-discriminating process by reason of imagery or the direction of attention to the events compared, there are disturbing factors of a general nature, as strong expectation for a loud or weak sound, and the varying intensity of the state of attention. If a loud sound is strongly expected, a weak one may seem weaker; if a weak one is expected, a loud one may seem louder. If the intensity of the state of the attention is sought to be kept at maximum, it will vary greatly, due both to its own rhythm and to the varying subjective conditions upon which it depends.

Improvement seems to consist in divesting the essential process of the unessential factors, freeing judgment from illusions to which the unnecessary and often fantastic imagery gives rise, and of obtaining a uniform state of attention which is less than the maximum: "Judgment does not require strained attention. All are quite certain or satisfactory. Don't see what the process is now—seems automatic," (Cr. May 12, IV).

And uniformity of direction of attention may also result: "Am able to abstract from visual image of the apparatus entirely, and yet refer the sounds to external stimuli. This seems to take the least effort and is more satisfactory," (Cr. May 17, IV). Many of the introspections of the various reagents, near the end of the training, were, "No imagery."

Our conclusion upon the experiment, therefore, is that efficiency in sensible discrimination acquired by training with sound stimuli has been transferred to the efficiency in discriminating brightness-stimuli, and that the factors in this transference of power are necessarily general rather than special in character.

b. Reaction with Discrimination and Choice

Reaction with discrimination and choice is also a relatively simple, definite, and measurable activity, which permits a change in both the motor expression and in the stimuli for the interpolated psychical process.

Identical motor elements were eliminated by employing a different kind of stimulus, and a different form of reaction, although the sense of sight received the stimuli, and reactions were made by the movements of the hands.

The object of the experiment was to determine the influence of improvement in the efficiency of one activity upon the *facility of improvement* in another already practiced. This influence could show itself either in lowering reaction-time in the latter, or making it more regular, or both,—which would be apparent in a practice curve of the tested ability.

Four reagents were trained, during the period of about 40 days (Cl. 46, Al. 41, Cr. 41, Bs. 27), for about 15 days (Cl. 14, Al. 13, Cr. 15, Bs. 11) in card-sorting; during which time about 4000 cards were distributed by each reagent (Cl. 4200, Al. 3800, Cr. 5200, Bs. 4000).

Before the training in the card-sorting the reagents were *trained* for 5 days in typewriter-reaction aggregating about 3000 reactions (Cl. 2900, Al. 2900, Cr. 2700, Bs. 3100) and after

training in card-sorting, for three days, aggregating about 1800 reactions (Cl., Al., Cr., 1800, Bs. 1700).

For the card-sorting we used a cabinet, similar to that illustrated in the Psych. Rev.[10] by Jastrow, which had six compartments (4¼ x 4¾ in.) in which to distribute the cards; and smooth round-cornered cards of buff-colored Bristol-board (77x52 mm.), in the center of which was painted in water-colors a rectangle (12x52 mm.), six colors being used: Red, Blue, Black, and Brown, in a quite heavy shade; and Yellow, and Green in rather a tint than a shade. The cabinet stood at a convenient height, and was entirely covered with black cloth to avoid distraction.

In card-sorting the reagent stood at the cabinet, and held in his left hand a pack of 50 cards, from the top of which he would grasp a card, turn it up sufficiently to see its color on the under surface, and toss it into its appropriate compartment. In about the middle of the training the color labels were removed from the compartments.

The cards were arranged into packs of 50, according to 12 different orders in which each color appeared about as often as another, each preceding and succeeding each other about equally often, and no color recurred with less than two intervening colors. (See Table XX, p. 274, for the orders.)

The assignment of the colors to the compartments was so made that the more apparent spatial relations of the latter would not correspond with the complementary or family relations of the former:

Brown	Green	Yellow
Blue	Black	Red

For the typewriter-reaction we used a No. 7 Blickensderfer typewriter, which was fitted up with a screen through a window in which but one letter could appear at a time. Series of letters were printed with the typewriter and cut into strips which could

[10] Jastrow: Sorting apparatus for the study of Reaction Times. Psych. Rev., 1898, 5:279-285.

be clipped to the 'scale-bar' and moved behind the screen by the 'carriage.' The spacing of the letters in the series and of the typewriter action being the same, the strip could be so adjusted that every stroke on the key-board would automatically present a new letter at the window in the screen.[11]

The various series were made up of 4 letters in such a way that each letter appeared about as often as another, and preceded and succeeded each other and itself about equally often. A letter was added to the beginning of each series the reaction to which was not counted. (See sample, Appendix B. Fig. 4, p. 289.)

In the typewriter-reaction the reagent sat at the machine and, holding his hands in position over the lower bank of keys so that the first two fingers could strike the first two keys on either side of the middle, reacted with the appropriate fingers, to the letters which appeared through the screen, the order of the keys upon which the fingers rested, from the left, being *a-t-e-n*. These were the letters used in constructing the series.

The time of reaction to each letter, as well as of the whole series of fifty was recorded in another room by electrical connections upon a kymograph drum which synchronously recorded seconds from a metronome.

The typewriter itself made records of the reactions which could be inspected for accuracy.

Efficiencies in both card-sorting and typewriter-reaction were calculated in time (seconds) and accuracy (errors) per 100 reactions.

(1) *Control Experiment*

In order to determine more definitely whether improvement shown in typewriter-reaction was due to the training in card-sorting, three reagents were trained in the typewriter-reaction (600 per day) three days before and two days after an interval of 45 days during which no training was taken.[12]

[11] The typewriter thus equipped constituted, in its essentials, Seashore's "Psychergograph" (vid. Univ. Iowa Studies in Psychol., 1902, 3:1-7).

[12] Owing to the imperfections of this control experiment, indicated in the

(2) *Results*

Table XXI (Appendix A, p. 275) gives the time and accuracy of successive hundred reactions on the typewriter for the regular reagents, both (A) before and (B) after training in card-sorting. The italicized figures represent the time of the first hundred reactions of the day's training.

Table XXII (p. 276) gives the daily average time and error per 100 reactions on the typewriter, for the regular reagents, both (A) before and (B) after training in card-sorting.

Table XXIII (p. 276) gives the time and errors of the successive hundred reactions on the typewriter for the control reagents, both (A) before and (B) after an interval without practice; Table XXIV (p. 278) shows the daily averages.

Table XXV (p. 282) gives the time and errors per successive 100 reactions of the regular reagents in the card-sorting training. The time of the first 100 in the day's training is italicized.

Table XXVI (p. 283) gives the daily averages of the same.

These last two tables and Plate XVI (p. 284) show that in the card-sorting training, maximal efficiency was approximately attained. The curves (Plates XVI and XVII, pp. 284-5) show lack of drop and are fairly regular.

From inspection of Tables XXI and XXII and of Plates XIII and XV (pp. 275ff) drawn therefrom, it may be seen how the practice in card-sorting affected the typewriter-reaction. The curves in the case of all reagents are lower, showing shorter reaction-time, and they are more regular, showing less variability.

(a) Errors

But the tables also show in the second training an increase of errors, and the question immediately presents itself as to whether the increase in speed, as shown in the tables and curves, has not been due to greater inaccuracy and therefore no increase

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following pages, a second group of four control reagents were later given practice equivalent to that taken by the Regular reagents. These later results are included in the tables and plates, although it is not possible to spare space for a qualitative discussion of them which would modify slightly their interpretation, because of their decisive contribution.

in efficiency is shown as the result of the card-sorting practice.

Calculation, however, shows that the records most responsible for reducing the time are also those which were made with the lower per cents of error (inspect records in Table XXI B), or, stated differently, that the higher per cents of error correlate with longer time and that the reduction in time has been made in spite of the increase in errors.

From the cord-sorting data (Table XXV) 32 time records, half with no errors and half with four or more errors, per 100 reactions, taken from the data of Al., Cr., and Bs.,—pairs taken from the same days in a manner to eliminate practice effect,—gave an average of 96.5 seconds per 100 reactions, with no errors, and 102.2 seconds per 100 with four or more errors.

From each of the last eight days of training (including three after card-sorting practice) were selected from the typewriter-reaction data (Table XXI), the time of the 100 reactions made with the fewest errors, and the time of the 100 reactions made with the greatest number or errors for the day. The data of each reagent were kept separate and the columns of time and errors averaged with the following results:

Cl.	with	0.06	errors	averages	66.4	sec.	for	100	reactions
	"	2.3	"	"	67.9	"	"	"	"
Al.	"	4.7	"	"	72.0	"	"	"	"
	"	9.9	"	"	73.0	"	"	"	"
Cr.	"	1.4	"	"	65.6	"	"	"	"
	"	5.9	"	"	68.4	"	"	"	"
Bs.	"	2.3	"	"	77.8	"	"	"	"
	"	7.9	"	"	81.6	"	"	"	"

The shorter time being correlated with the fewer errors cannot be accounted for by the possibility that the selected records of the fewer errors have occurred in the latter part of the day's practice and hence would represent a disproportionate amount of daily practice-effect, for the records of the greatest number of errors have occurred later in the day's practice just once more than those of the least number of errors.

Introspections from all reagents support the showing made

by the above data as to the relation between errors and speed: Cr. said, "Made mistake and was bothered thereby," (March 3), "Errors result in confusion and pauses," (March 15). Al. remarked, "the large number of mistakes impedes rapidity, as one is troubled by them," (April 27). And Bs. noted, "mistakes were noticed and caused confusion at the time," (March 20). For these three reagents, errors reduced the speed by confusing or vexing them; but for Cl., by inducing introspection: "I do not care for the making of a mistake in and of itself, but I always pause to think of it and wonder why, and that lessens my attention to the business in hand," (March 1); "The time I spent thinking of a mistake caused a delay," (Feb. 24). Our errors in reacting are thus causes of decrease rather than of increase in speed.

As a matter of fact the errors are not greatly increased as may be seen from the daily averages in Table XXII: for Cl., Cr., and Bs., the increase is less than 2% in the second training in typewriter-reaction; for Al. they increased but 6%, and much of this may be accounted for by the fact that Al. fell more heavily under the unfavorable conditions of the second training, to be noticed later, than did the other reagents.

Some of the increase in errors for all reagents is undoubtedly the result of the same unfavorable conditions of the second training, and some of it is due to the inability to inhibit anticipatory reactions during the rapid rythm of the later practice, which had been inhibited in the slower rythm of the earlier practice. This latter fact is also supported by evidence from introspection, *e.g.*, when reactions were running 73.5 sec. per 100, Cl. said, "Several mistakes inhibited," (March 1), and after practice had reduced the time to 63.3 sec. per 100, she said, "Was running quickly; reaction simply came before I could inhibit making mistake of an *a* for an *n*," (March 10). The increase of errors may not mean that the efficiency of reaction to letters is less therefore, but that facility of reaction has increased to such a speed that anticipatory reactions previously inhibited are now made before they can be inhibited. And the error once made, the speed is retarded.

In comparing efficiencies in the typewriter-reaction, therefore, we may look upon the time record as a satisfactory measure.

For the purpose of learning whether the more unstable associations between the various letters and their proper reactions of the first training were also those of the second training, the errors of the whole period of training in typewriter-reaction were collected and classified. The weaker associations were the same for both periods. For Cl. *e* and *t* were interchanged more than any other two letters, and *a* and *t* were the second pair in instability; for Al. *a* and *t*, and *e* and *t;* for Cr. *e* and *t*, and *a* and *t;* for Bs. *e* and *a*, and *e* and *t*. The card-sorting did not change the peculiarities in the errors of the respective reagents.

There were probably six causes for the errors: (1) Lack of coördination between the letter and its proper reaction, (2) anticipation of a letter in which the reaction took place before the letter was cognized, (3) false cognition of the letter, (4) reaction incited by rhythm without recognition of the letter, (5) misplacement of the fingers on the keys, and (6) raising a fairly automatic process into clearer consciousness and giving the control for the moment to voluntary attention. The 4th and 6th causes enumerated are probably the chief factors in the increase of errors in the second training.

(b) Time

The gradual improvement made in the card-sorting may be seen in Table XXV (p. 282) and on Plate XVI (p. 284). If the first and last 400 reactions are taken for calculating initial and final efficiencies, the training resulted in the following practice-effect, in decrease of time: Cl. 23.5%, Al. 28%, Cr. 22%, Bs. 30%.

The decrease in time in the second training in typewriter-reaction is noticeable in both Tables (XXI, p. 275, XXII, p. 276) and Curves (Plates XIII, p. 279, XV, p. 281).

But inspection of the Tables XXIII and XXIV (pp. 276-8), and Plates XIV (p. 280) and XV (p. 281) of the control reagents shows that they also improved in speed after their unpracticed interval, which suggests that the improvement of the regular

reagents may not have been the result of the training in card-sorting, and invites an examination into the relative facility of improvement.[13]

The curves of the regular reagents, after training in card-sorting, show more improvement in regularity than do those of the control reagents, after the unpracticed interval; they also show the drop in time to be greater (except in the case of Ge., whose curve is quite abnormal). (The line through the curves shows the average of the last day before card-sorting.)

To express quantitatively the relative improvement in speed, data were selected from Tables XXI and XXIII and arranged as is found in Table XXVII (p. 283). The average reaction time per 100 was found for the second and third days of training for both regular and control reagents; with this was compared the average time per 100 for the 4th and 5th days of training, which followed the 2d and 3d in continuous training in the case of the regular reagents, but which came after the unpracticed

[13] To indicate the pitfalls for the statistician who is so completely absorbed in the tables of quantitative results as to neglect the processes involved in producing the results, a recent reviewer may be aptly quoted at this point: "Nothing whatever is needed to account for the improvement in typewriting save the special practice in it" (Thorndike: Educational Psychology, vol. II:407): the average "improvement from the first three days before training to the second three before training is greater than the improvement from the three before, to the three after, training" (*op. cit.*, 406); as though one might expect considerable improvement in this typewriter-reaction after the practice-effect of 3000 reactions which for half of the trained reagents had produced about maximal efficiency. And it is claimed that the control reagents "show no inferiority" to the trained reagents (*ibid.* 407); whereas, as is shown later, the gain during the interval by the only control reagent whose results are comparable to the others is exceeded by the gains of the trained reagents Al. and Bs. and about equaled by the gains of Cl. and Cr. for whom, the averages of the table might have suggested, the reactions had become automatic.

Apart from the unwarrantable aggregating of results so disparate in efficiency (or their place on the practice-curve), and a disregard of the analysis in the text, the reviewer's error is minimized by the fact that by chance only the daily averages were accessible to him. The curves (pp. 279ff) plotted by successive 100 reactions show the facts more clearly, and, if examined with the cautions noted in the text, will, in all probability, clear the authors of the charge that they "endeavor to extract evidence" (*ibid.* 408) of transference. The facts would then seem to prove the conclusions.

interval in the case of the control reagents. The gain made by the control reagent Mn. (7%) is about the same as that made by the regular reagents (Cl. 6%, Al. 0.8%, Cr. 3%, Bs. 8%) in continuous practice. (We disregard Ge.'s data—16%—here as abnormal, for reasons given later, and because they represent series of reactions in which frequent and often long lapses of attention played a great part). Mn. shows gain as a result of the interval. But comparison of the average time per 100 reactions for the last two days before training in card-sorting with the average for the first two days after training shows the regular reagents to have gained more than Mn. after the unpracticed interval (Cl. 6%, Al. 16%, Cr. 5%, Bs. 12%), except in the cases of Cl. and Cr., to be noticed later, in which the gain was about as much.

A comparison of the results in Table XXVII (p. 283) as well as of the curves is misleading unless several things are borne in mind, the principal of which are (1) that the control reagents had trained but three days (Gs. one day) before their unpracticed interval, while the regular reagents trained five days before their training in card-sorting, and for that reason the former would be expected to show more improvement in their second training as a result of practice in that training; and (2) that the control reagents in their training before the unpracticed interval showed comparatively long times from which great improvement in both absolute amount and per cent could be made before much skill would be shown: the last daily average before the interval, for Mn., is as high as the first daily average of two of the regular reagents (Cl., Cr.), and for Ge. almost as high as the first daily averages of the slowest regular reagents (Al., Bs.).

With these facts in mind the comparison of averages in Table XXVII (p. 283) of the curves on Plates XIII-XV (pp. 279ff) discloses *a noticeable improvement in regularity in the cases of Cl. and Cr., and a marked improvement in speed in the cases of Al. and Bs., which is attributable to the training in card-sorting.*[14]

[14] The curves of the second group of control reagents (Bd., Bh., Bs. 2, and Cf.) compare favorably, in time, with those of the regular reagents Cl. and Cr., for whom the processes had become automatic, but they contrast mark-

Some explanation might be offered for the fact that the improvement in speed was not more marked. First, we had sought to determine the effect of training in card-sorting upon the practice-curve of typewriter-reactions. But the typewriter-reaction curve had already attained to records of approximately the *maximum* speed for both Cl. and Cr. Cl. is skilled in piano-playing, and Cr. in typewriting. They trained for five days before the point was reached where the influence of another training should be determined.

On the second day of practice Cl. remarked, "The fingers begin to react at the mere sight of the letters now"; on the third day, "Reacting today is growing more mechanical;" and on the

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edly with those of Al. and Bs., indicating more certainly than was done before the influence of the card-sorting practice. The particularly significant comparable curves are those of the regular reagents Al. and Bs. and the control reagents Cf. and Mn.

Some slight additional evidence in support of the hypothesis of a functional relationship between the two kinds of reaction we have employed is afforded by an auxiliary experiment in which the influence of practice in typewriter-reaction upon card-sorting was tested. The four reagents, mentioned above and on pp 52f as the second group of control reagents, served in this experiment as the regular reagents, practiced by 4000 typewriter-reactions each. Immediately before and on the last day of that practice they sorted at one sitting four packs of 50 playing-cards into four compartments labeled Diamonds, Spades, Clubs, and Hearts:

D	S
C	H

The intervals between sortings were 58 days for Bd., Bh., and Bs. 2, and 44 days for Cf.

Two control reagents, Cn., and Sn., sorted four packs each, before and after intervals of 56 days and 53 days respectively.

Both groups of reagents had had extended practice throughout the preceding semester in sorting playing cards by suit according to a different method. They sorted in piles upon a table instead of into compartments, and sorted to the place of the preceding card instead of to the place of the card held. All were therefore nearer practiced condition in sorting cards before the interval than after it, which may account for the loss of the control reagents.

One of the regular reagents (Bs. 2) was suffering from a severe cold on the day of her final sorting and shows no improvement; the others seem to have carried over some practice-effect from typewriter-reaction to card-sorting, as may be seen from Table XXVIII (p. 286) and Plate XVIII (p. 287).

fifth day, "Reaction to the sight of the letter is so automatic that I can think of other things as I operate. . . . During the reaction attention was not well concentrated at times because I was thinking of the influence of thinking about your rate of speed upon your speed." Reacting had obviously become automatic. And Cr. on the third day of training remarked, "reacting is becoming very mechanical." Hence in these two cases we have determined the effect of training in card-sorting upon typewriter-reaction after it had already been trained to a high degree of automatization. The cases of Al. and Bs. are different. Neither is skilled in typewriting, although each had used a typewriter, and Al. remarked, "No application of former practice with the typewriter,—motion a new one," (Feb. 24). They did not speak of the process as being automatic before the card-sorting began,—and they show greater practice-effect.

Another reason may be given for the reduction in time not being more marked. The second training on the typewriter was taken by the Regular reagents during April 26-28 while everybody was rushed with work preparing for the closing of the semester, and meeting the many social duties coming at that time, all of which occasioned general fatigue in at least three of the reagents. Cr. took the first day's work in the second training so late that the room was dusk and his attention was almost wholly directed to the perception of the letters: "Had to strain to perceive the letters; this part of the process demanded all the attention; some errors are due to mistaking at first the letter outline" (April 26). Al. was doing heavy work day and night: "Reagent very tired, cannot hold attention; up till 1 o'clock preceding night busied with exhausting and harassing work" (April 27). And Cl. noted, "Have been up late for six out of seven nights past and feel somewhat below normal."

But the most marked effect of card-sorting on the typewriter-reaction is shown by introspections. On the first day of the second training Cl. remarks, "Sight of letter produced the reaction movement without my thinking of my fingers and not at all of the sight of the keys" (April 26). Al. remarked, "No

headache, no nausea, as before card-sorting," "Much easier than at first"; "General background of feeling is probably not unlike that of card-sorting, but I did not think of the card-sorting during the trial" (April 26). Cr. said, "Process was surprisingly automatic and was accompanied with ease" (April 26); "seems more automatic than ever before, and even more so than the card-sorting. I do not pay slightest attention to the fingers or the keyboard when the process is going best . . . it appears that the old associations have not only not been interfered with by forming new ones in card-sorting but that they have become firmer and action upon them more ready and automatic than it was before or than it was in card-sorting," (April 27). On the last day of typewriter-training before card-sorting began, Bs. remarked, "Pauses between letters caused by having to think which finger I should put down," and on the first day after card-sorting, "Seemed more natural than I thought it would," and the next day, "Seemed more natural to react today, demands less attention, tendency to become automatic."

The introspections of the control reagents, none of whom was familiar with typewriting, show that while some ease and facility were experienced before the interval, reaction afterwards seemed unexpectedly "difficult" and "unhandy:" Mn. stated in the second training that "Reacting seemed difficult," "Seemed to have to stop to think which finger was to react to the different letters." Ge. in the training before the interval said, "The reactions are becoming more automatic," and afterward, that he "looked at letters not knowing what to do" and that "combination of letters here was particularly unhandy," The interval without practice resulting in a feeling of discomfort and difficulty, strengthens the point of the preceding paragraph that the training in card-sorting is the cause of the increased ease and facility experienced by the regular reagents in the second training in the typewriter-reaction.

(3) *Conclusion*

We conclude, therefore, from the results of this experiment, that training the activity of reaction with discrimination and

choice by sorting cards into compartments has increased the facility of the same activity in both speed and regularity in typewriter-reaction (a) noticeably in regularity in two cases after the latter had become automatic, and (b) markedly in speed in two others in the course of practice.

The cause of transferred facility could not have been identical motor elements. In the typewriter-reaction the eyes rested sharply fixated upon one spot on the screen while the fingers, with coördinating wrist and forearm movements, tapped down the keys, accessory muscles being mainly used; in the card-sorting reaction the eyes moved from the cognized colors on the cards about over the compartments of the cabinet or followed the movement of the hand and fixation was nowhere so intense, while the right arm contributed most of the movement in grasping the cards, turning up the under color-surface, and casting them into the compartments, using mainly fundamental muscles.

Neither could the cause have been habituation to the stimuli, for they were different in character: one being a small symbol (form) and the other a comparatively large rectangular surface of color.

Nor was the cause identical associations between stimuli and reactions.

According to the introspections of the regular reagents on their card-sorting training, the process of reaction is variable. At the beginning of training they matched the color of the cards with the labels on the compartments then to increase speed a system of mnemonics is employed designed to form associations in the mind between a compartment and its color; this system then goes through a process of mutation—becoming abbreviated, changed in part, or supplemented,—or is superseded by another; finally, through repetition reactions to particular compartments become coördinated with their respective colors and are made directly, free of the system except in cases of emergency. Synchronously with the growth of these coördinations, adventitious processes, as pronouncing the color when cognized, movement and strain of the whole body, and disadvantageous movements of the hand, decrease to a minimum.

According to the introspections of both the regular and control

reagents on the typewriter-reaction, the process of reaction goes through precisely the same stages, except that it starts with a system of mnemonics, and systems are superseded more often. No two systems are alike. But all finally give way to the direct reaction which has been coördinated with its letter. Adventitious processes, as pronouncing letters upon cognizing them, visualizing keys, fingers, on their order, likewise decrease to a minimum.

These two processes so summarily described are necessarily related to their particular stimuli and their appropriate reactions, and seem therefore fairly independent of each other. But there is one *common factor* already apparent: *The habit of stripping the essential process of its adventitious accessories.* This is one of the causes of transferred facility, and we shall notice two others.

Introspections also state that in any one series several systems of mnemonics may be operative; there may be some direct reactions due to coördination of stimulus and reaction, some due to a kinaesthetic image of recent reaction; that in one part of the series one stimulus causes difficulty and in another part another stimulus; that some stimuli are harder than others throughout the whole series. Improvement here seems to consist in resolving the reaction process to a single type, except in so far as reactions become direct, and to attend somewhat more closely to the difficult stimuli until their reactions become as ready as those to the other stimuli; but also, not to confine attention so closely to the troublesome stimuli that their reactions anticipate other stimuli and cause errors thereby.

Again, introspections and records show that even after a mnemonic system has been successfully applied and has served to bring stimulus and reaction to a fair degree of coördination, lapses of attention occur during which the "mind is a blank," and the drum records abnormally long reactions. Improvement here consists in keeping attention upon the matter in hand so constantly that irrelevant stimuli are unnoticed.

We find, therefore, the causes of the transference of facility to be (*a*) *the habit of reacting to a stimulus without being delayed by prominent kinaesthetic, acoustic, and motor accom-*

paniments of recognition, through gradually dropping these out of the process, or reducing them to a minimum; (b) an equitable distribution of the attention to the various possible reactions so as to be about equally prepared for all; and (c) the power of concentrating upon the process through a whole series to such a degree as to eliminate distraction.

II. PRINCIPALLY QUALITATIVE

Experimentation thus far had pretty well established the fact of the general effect of special practice, but there is not yet a general agreement in the interpretation of the results, as to extent and causes of transference of practice-effect; and in almost all investigations there stand out anomalous cases which remain unexplained.

Most of the introspective analyses of practice effect show it to be extensively general in both positive and negative influence, but Sleight argues from the paucity of 'significant' values in his tables that it is narrowly specific. Ebert and Meumann found training-effect to be permanent for at least three months; Sleight interprets his evidence to indicate that "the effects of both 'direct' and 'indirect' practice are usually not permanent."[15] Fracker

[15] *Op. cit.*, p. 451.

The effect of practice is found to be more permanent than the opposing factors of interference (Bair: The Practice Curve. Psych. Rev. Mon. 1902. 5:No.2, and Bergström: An experimental study of some of the conditions of mental activity. Am. Jr. Psych., 1893-4, 6:272) and fatigue (Kraepelin: Die Arbeitscurve. Phil. Studien., 1902, 19:476; also, A measure of mental capacity. Pop. Sci. Mo., 1896, 49:760), and although some studies show that the greater part of it is soon lost (Kraepelin: *loc. cit.*), it may endure for a long time:

Kraepelin found that two hours of practice in adding left noticeable traces three months afterward, and that the effect of 17 presentations of associations was perceptible 1⅓ years later (*op. cit.* S. 476).

Ebbinghaus (Grundzüge der Psychologie, 2te Auf. Bd. I. S. 633) saved 7% in number of repetitions upon relearning stanzas from Byron's Don Juan after an interval of 22 years; and 20% after an interval of 17 years.

Bourdon (Recherches sur l'habitude. Année Psych. 1901. 8:327-340) found that skill acquired in marking out letters in a page of print dropped

found the greatest cause of improvement and transference in memory of simple sounds or shades, to be the development and carrying over of representative imagery of a very simple and definite type; while Ebert and Meumann found that in training on non-sense syllables the use of, and dependence upon, representative imagery of all kinds dropped away. And Fracker is inclined to oppose his results to those of Coover and Angell because the latter pointed out the function of representative imagery in the processes of discrimination, and of reaction with discrimination and choice, to be respectively a distraction, and a temporary but probably a necessary means of effecting automatic coördination between stimulus and reaction.

Almost all investigators conclude that when transference of practice-effect takes place, it varies in amount with the similarity of either the material or the method of the tests to the practice, and there seems no reason why one should not hope for this law to be finally established. But, so far, either the ways in which practice and training may be similar must be multiplied and further defined or the exceptions to the law appear, upon inspection of the results, to be the rule. A few of the anomalies, for the purpose of illustration, follow:

From the results of Thorndike and Woodworth, we note that the average gain in training on estimating areas was about 52%, that tests on the same form within the field of change of area in training yielded an average of 61%; but that above the field, same form, 16%; while above the field, different form, 51%. Again, one reagent (W) in training on estimating

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very little during a rest of 236 days; and that most of it remained at the end of a rest of seven years.

Book (Psychology of skill, with special reference to its acquisition in typewriting. Univ. Mont. Bull. 1908. 53:75) found effect of practice in typewriting to persist after a rest of one and a half years.

Swift (Relearning a skillful act: An experimental study in neuro-muscular memory. Psych. Bull. 1910. 7:17-19) found skill in tossing balls to be retained 275 days; and that it could be rapidly regained after an interval of 6 years. Skill that had required 42 days' practice to attain was regained in 11 days. In the last "try" of his test he exceeded his former skill, in number of catches, in the ratio of 1600:1051.

weights made 49% improvement, while estimating objects within the field of training he made 62%.

In Ebert and Meumann's research we found improvement in 'immediate memory' for non-sense syllables (the training material) to be 20%; while for numbers it was 29%, and for letters, 36%; if the grade of memory at "two-thirds correct" is considered, for non-sense syllables it was 49%, but for numbers 56%. In 'complete learning,' for non-sense syllables it was 61%, for poetry 20%, but for prose it was 43%. One would surmise that the more arbitrary sequence of words in poetry would make it more similar than prose to the training. Retention after 24 hours, of non-sense syllables, was improved 45%, but of optical symbols 49% and of prose 67%.

From Fracker's research we found the average gain in training upon memory of sounds 21%, and the average gain upon the test on grays 36%, seven of the eight trained reagents gaining more in this test than in the training. Reagents exceeded their training gain in other tests also: on nine tones, 4 reagents; on nine grays, 4; on four pitches of a tone, 2; on geometrical figures, 3. From the monograph, we learn that F. S., "a graduate student in psychology, who was trained in many forms of experiment" (p. 64), trained on sound 8 days, taking four sets of 75 sounds each, per day; he started at 70% reproduced elements, and finished with 40%, while three of the other reagents finished near or above 90%. In spite of his inverted practice curve he shows gains in his tests, however. If his most efficient imagery was auditory, as it seems from introspections upon training, and his test on four pitches (p. 82), to have been, how did he by a change of method make his greatest gain (26%) upon the four grays, and how make so little gain upon nine tones (1%), and upon nine numbers (4%)? Another reagent (H. C. E.) who developed during training a very definite visual system of imagery involving four positions, made more gain upon the square of geometrical figures (35%) than he did in training (27%), and less upon the four pitches (23%) than upon the figures.

From Sleight's research we noted that of the three trained

groups of children, but one group showed improvement in the tests more similar in material to their training and that according to the two sets of data there are scarcely any correspondences between the 'significant' values of the children and the adults.

It is probable that the conflicting nature of results rests largely upon differences in detail of experimental procedure: the kind and length of training, the kind, length, and number of tests, and the manner of scoring and comparing results.

The paucity of 'significant' values in Sleight's tables may indicate merely that (a) the training-effect of practice on the trained groups is but slightly greater than the training-effect of other school work upon all the reagents; (b) statistical treatment smothers the facts: *e.g.,* with a probable error of 16, and a difference-score of 53, a 'significant' value would necessitate a gain of 30 points in the second test over the first when the average score in the first was but 66.8 (Group 2, on points),[16] which means that if the gain in the second test is not about half the initial capacity it cannot be considered really significant; (c) the probable error is unduly large, by reason of widely differing initial efficiencies of individuals (in the test on points initial efficiencies ranged: for School X 27-93, for School Y 32-129, for School Z 23-132).[17] Where individuals differ so greatly in capacity, we learn in following experiments, they are not doing the same thing, not applying themselves to the same kind of work.[18]

The permanence of training-effect found by Ebert and Meumann may, as Sleight thinks, be due to the inadequacy of the per cent method of expressing results, or to greater ease of the later tests; again, it may be due to the rigor of the training, which greatly exceeded that of Sleight's reagents.

The usefulness of representative imagery found by Fracker may be largely due to the small number of separate units of

[16] *Op. cit.,* Tables, pp. 413-417.

[17] *Idem,* Table I, pp. 410-411.

[18] Hollingworth (Individual differences before, during, and after practice. Psych. Rev., 1914, 21:8) upon the basis of low correlation in early practice changing to high correlation in later practice, concluded that in the early trials he was not "measuring the same thing with all performers."

which his series were made up, and to the simplicity of the stimuli, both of which conditions were foreign to the training material of the reagents of Ebert and Meumann.

The anomalous cases may be due to inadequate methods of comparing results or to a radical change in the reagent's processes.

If the initial capacities of two reagents are not about equal, and the improvement is made through increasing the number of units of work within a given time, not only will the difference-score of the lower capacity have the advantage of the higher, because of more room for improvement, but expression in per cent of gain will exaggerate this advantage. (When the score is reckoned in decrease of time taken to perform a given amount of work, the expression of the score-differences in the form of per cent, of course, compensates in a measure the advantage of the low initial capacity).

That some anomalies are the result of radical changes in the reagent's processes may be illustrated by a few cases reported in experiments some pages back (pp. 38ff.). In the word-marking experiment Gs. made his lowest gain on *s-p* words (15%)[19] when the material was similar to that used in the training, while on material different from the training he averaged 30%—in spite of the fact that the per cent form of expression tended to reduce the inequalities among initial capacities. Upon inspecting the table[20] we note that his initial capacity was about twice as high as in the other tests. Introspections state that his method of marking *s-p* words in the first test was radically different from his method of marking other words:[21] he took *p* for the cue and ran his eye along under the line for the projecting stem; he took advantage of the form of the letter to turn from hunting letters to hunting a certain rare but easily recognizable projection. In the second test he hunted for letters. His low gain in marking out *l-o* words from manuscript pages was due to a similar change in process:

[19] *Vid.*, Table I, (Appendix A., p. 259).
[20] *Vid.*, Table II, Plate I, (Appendix A., pp. 260, 261).
[21] P. 38.

he sought above the line for the loop of the *l*, to the first test. Cr.'s low gain on *s-p* words was owing to the same cause.

In the weight-estimating experiment, Cr.'s great loss on objects outside the field was owing to greatly over-estimating the weights of two of the ten objects—a bottle of muscilage and a volume of the Psych. Rev.[22] He used in both tests on this series of objects, as a basis of judgment, a kinaesthetic image of a 1000-gram weight accidently handled some days before the first test, and it served more poorly for the second test since it was more vague,—a process very different from his estimation of the other series of objects.

Large differences in an individual's results appear to be due to a radical change in processes and for that reason do not seem properly comparable with his other difference-scores—the scores in question do not measure the same kind of work. Whether great variation in initial scores of different reagents make them, for the same reason, non-comparable, remains for analyses of processes to determine; if they are non-comparable, no other statistical device is likely to prove more satisfactory in comparing them than the absolute or the per cent form.

Evidently we need to know more about (a) the extent of variability in processes, with a single reagent and between different reagents,[23] who set themselves to the same objective task;

[22] Table X, (Appendix A, p. 265).

[23] Contributions to individual psychology show us that individuals may vary tremendously in their mental processes, *vid.*

Binet et Jassey: Étude de psychologie sur les auteurs dramatiques. Année Psych., 1895, 1:60-118.

Binet et Henri: La psychologie individuelle. Année Psych., 1895, 2:411-465.

Toulouse: Enquête medico-psychologique sur les rapports de la supériorite intellectuelle avec la névropathie. 1896.

Oehrn: Experimentelle Studien zur Individualpsychologie. Psych. Arbeiten., 1896, 1:92-151.

Binet: L'Étude expérimentale de l'Intelligence. Paris. 1903.

Sharp: Individual psychology: A study in psychological method. Am. Jr. Psych., 1899, 10:329-391.

Whitley: An empirical study of certain tests for individual differences. Archives of Psych., 1911, 3: No. 19.

Also the studies which attack directly the problem of the Diagnosis of mental imagery (like those of Secor, Segal, and Fernald) or which make

(b) the causes of this variability; and (c) its effect upon the scores. We might then be able to determine more precisely how training affects the processes engaged in the training, how training-effect affects the test-capacities, and how these facts may be properly expressed in quantitative terms.

To this task of qualitative analysis we set ourselves in the following two experiments, and at the risk of tedium we report on both tests and training as fully as our introspective data permit.

1. Experiment on Attention. (Variability in Mental Processes).[a]

In order to give greater opportunity for variability and for functional relationship of processes to appear, it seemed desirable to extend more than is usual the variety of tests and training; the variability for the large number of tests and different kinds of training could be worked out in detail and thus furnish a basis for a critique of this type of experiment, while functional relationship, at the risk of not being found at all, might be detected where it is scarcely expected, thus revealing some new causes for general effect of training, both positive and negative.

Fortunately there is an excellent opportunity for organizing a number of variously related tests into this standard type of experiment. In many of the discussions psychologists have attributed the general effect of special practice, in part, to training in attention.[24] In the want, as yet, of any direct method of

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an analytical inspection of the memory process (like those of Kuhlmann, Gamble, Cohn, Sybel, Wreschner, and Müller), as well as the early work in which the concept of "imagery types" was originated and developed (Fechner, Galton, and Charcot).

[a] Performed during the year 1910-1911.

[24] *Vid.* Angell, J. R.: The doctrine of formal discipline in the light of the principles of general psychology. Ed. Rev., 1908, 36:8.

Aall: in review of Coover and Angell. Zeit. f. Psych., 1908, 48:303.

Müller: Zur Analyse der Gedächtnistätigkeit u.d. Vorstellungsverlaufes. Zeits. f. Psych., 1911. Erg. Bd. S. 244. Ebert und Meumann (*op. cit.* 205), Fracher (*op. cit.* 95), Sleight (*op. cit.* 442-3). Stumpf (Tonpsychologie, 1:81).

measuring attention,[25] lies our opportunity. If attention can be measured at all,[26] and, in view of the fact that it is often practically gauged by casual observation, it seems reasonable to hope that it can, it must be measured by the product of such mental activities as are known to depend in the highest degree upon the attentive state. Such activities are sensitivity, sensible discrimination, reproduction, and voluntary activity;[27] and a large number of fairly standard tests are at hand which may be used to measure them.

If we get the initial capacity of a number of reagents in a number of these tests, we may be said to have obtained indirectly a cross-section of their initial capacity in attention. Then, if special training is given to some of them, and the tests are given to all of them again for a final measure of attention, our experiment will conform to the type usually employed in our field of investigation.

Although we are for the moment assuming that attention is a simple and uniform state of consciousness, we may, perhaps, have to recognize (a) that there are phases or 'moments' of attention[28] such as degree of concentration, quickness of adaptation, and duration of concentration; and (b) that individuals might possess (1) different types of attention,[29] such as broad or narrow spanned, alert or sluggish, visual or auditory or motor, or (2) different types of consciousness,[30] such as dual or multi-level.

We may then, provisionally, call this an experiment on attention; our chief aim being to learn the extent and causes of variability in processes engaged in tests and training of widely different kinds, incidentally, to trace through introspective

[25] In 1893 Külpe wrote: "The discovery of a reliable measure of the attention would appear to be one of the most important problems that await solution by the experimental psychology of the future." (Outlines of Psychology. 1901. Sec. 73.2). And in 1908 Titchener said: "The discovery has not yet been made" (Lectures on the Elementary psychology of feeling and attention. 1908, p. 276) which still remains true.

[26] For present methods of measuring attention see Titchener (*ibid.* 276ff), and Pillsbury (Attention. ch. VI.).

[27] *Vid.* Külpe: *op cit.* Sec. 73.

[28] Chase: Some aspects of the attention problem. Ped. Sem., 1909, 16:281.

[29] McComas: Some types of attention. Psych. Rev. Mon., 1911, No. 55:55.

[30] Geissler: The measurement of attention. Am. Jr. Psych., 1909, 20:473ff.

analysis the functional relationship between sets of processes varying more or less from the training in kind, when applied to tests varying more or less from the training in material; and in case we get sufficient data which may be justly compared, we may be able to determine whether improved attention is a cause of general effect of special practice.

a. The Tests

The following tests[31] were chosen because of their dependence upon attention:

I. Reaction
- 1. Simple sensory to sound............................(50)...... 1
- 2. Compound
  - a. With discrimination
    - (1) Marking out small a's..................(100)...... 2
    - (2) Marking out o's......................(100)...... 3
  - b. With discrimination and choice
    - (1) Card-sorting ....(200)...... 4
    - (2) Typewriter-reaction ....(200)...... 5
    - (3) Controlled reaction ....(50)...... 6

II. Sensible discrimination of sounds..........................(90)...... 7

III. Reproduction
- 1. Unequivocal (Rote memory)
  - a. Successive presentation
    - (1) Memory of sound intensities............(50)...... 8
    - (2) Memory of consonants ....(50)...... 9
    - (3) Memory of Arabic numerals............(50)......10
    - (4) Memory of visual signs................(10)......11
    - (5) Memory of associated pairs.............(50)......12
  - b. Simultaneous presentation
    - (1) Learning 12-letter-rectangles
      - (a) Free ....(10)......13
      - (b) With distraction ....(10)......14
- 2. Equivocal—Word-completion ....(10)......15
- 3. Free—2-minute trains of ideas......................(3)......16

IV. Extensive threshold of visual attention
- 1. Free ....(15)......17
- 2. With distraction ....(10)......18

V. Maximum voluntary activity—tapping ....(5 30″)......19

(The figures in parenthesis indicate the number of reactions, memory units, or experiments, in the test.)

[31] How these tests are related, in method or material, both to laboratory work and to standard mental tests, is indicated by some representative bibliography given with the discussion of Test Results (pp. 106ff.).

These tests were taken by 10 reagents, 8 of whom took training between the first and final series which were separated by an interval of 55 days. The first series of tests occupied 12 days during a period of 36 days; the second, or final, 10 days during a period of 21 days. Each pair of tests was separated by an interval of about 66 days.

The pairs of tests were also taken by two reagents of a group of 21 control reagents. There were thus two sets of control reagents: The two who took all the tests, and the 21 each of whom took only one pair or a few pairs of tests.

The conditions of the final tests were as nearly identical with those of the first as circumstances permitted. The material was also identical with the exception of the Tests 4 and 5, in which the orders of the symbols were changed to avoid learning sequences of reactions.

Of the reagents who took training, 7 had training in advanced psychological laboratory work; 1 had no training. Of the first group of control reagents (2), 1 had training. Of the second group (21), one was taking elementary laboratory work; the others were in a class of general psychology. The students of this second group represented nine departments in the university; there were two graduates, eight seniors, five juniors, and six sophomores. On the whole they ranked younger than the other two groups.

b. The Training

During the 55-day interval between the tests, two reagents (Mn., Le.) took training 18 days on Test 17; 25 12-letter-rectangles were presented daily, making in all 450 experiments each. Two reagents (Rt. and Sl.) took training 18 days on Test 13; 20 12-letter-rectangles were presented daily, aggregating 360 experiments each. One reagent (Ly.) took training in simple reaction to sound for 11 days, 1100 reactions in all. (Le., who took training on test 17, also took training in this simple reaction to the extent of about 500 reactions). Two reagents (He., Cr.) took training on memory schemes for about 14 days.

And one reagent (Al.) took training on Test 17 for 8 days, almost consecutive, to the extent of 200 experiments.

In the training as in the tests introspections were written or dictated.

c. Apparatus and Procedure

(1) *Reaction to Sound*

For simple reaction to sound, the Morse key (set at a tension of 100 grams, and an amplitude at the button of 3 mm.) was released by raising the index finger of the right hand. The reagent was instructed to lay the arm and hand on the table forming a hand-rest by folding in the fingers and extending the thumb and to give a stimulus-direction to attention. No apparatus except the key was visible to the reagent, the Wundtian sound-hammer[32] for presenting the stimulus being located a meter to the right and back of his head. The whirr of the chronoscope could be heard from the adjoining room and acted as a second signal. A "ready" signal was called at irregular intervals from two to five seconds before the stimulus was given. After reaction the reagent noted introspections and called "ready" for the next experiment; he was practiced before the experiment and the first three reaction-times of the first daily series, and the first reaction-time of the other series, were discarded. The Hipp chronoscope was tested daily with a fall-hammer[33] and its MV. found to be less than 1.5 sigma. Twenty valid reactions were taken on the first day; 30 on the second.

For each series of 10 reactions were found the (a) arithmetical mean, (b) probable error, (c) standard deviation, (d) PE of the standard deviation, and (e) coëfficient of variation,[34] besides the (f) MV. and the (g) relative variation.[35] These were averaged for the five series of the test. Inspection showed, however, that owing to the increased sensitiveness of those

[32] Illustrated in Wundt: Grundzüge der Psysiol. Psych (5 te Auf.), III:503.
[33] Illustrated, *ibid.*, S. 397.
[34] *Vid.* Titchener: Experimental Psych., Vol. II, Pt. II, p. 361.
[35] *Vid. ibid.* Pt. I, p. 181. r.v.=MV.x100/M.

measures which rest upon the square of the deviations from the mean, over the MV. and the r.v., for occasional large deviations (yet not sufficiently large to discard),[36] the former possessed no advantage over the latter which alone were consequently retained.

(2) *Marking Out a's*

The reagent was instructed to mark out all the small *a*'s between the pen marks across a printed page. The material consisted of page 12 of Horace Davis' Phi Beta Kappa address on Vocational Training, delivered at Stanford University, May 8, 1909. Between lines 2 and 30, inclusive, there are 100 small *a*'s. The page was placed before the reagent right side up, covered with a screen which was removed at the moment the stop-watch was started for timing the test. Introspections were written after the test.

The Efficiency Index was computed according to Whipple's formula.[37] Since no letters were wrongly crossed out, the Efficiency Index became the "time per 100 reactions."

(3) *Marking Out o's*

Page 13 of the same material as above was used for marking out small *o*'s, of which there are 100 between lines 1 and 30 inclusive. The page was placed before the reagent *inverted*. Further procedure as above.

Tests 2. and 3. were taken in a single sitting.

(4) *Card-Sorting*

A Jastrow[38] cabinet of six compartments, and four packs of 50 cards (6 x 8.5 cm.) were used for card-sorting. The cards were not glazed but were smooth and fairly stiff. In a central position at one end they bore a printed device (14 mm. in

[36] Times with deviations greater than 4xMV. were discarded.

[37] Whipple's Manual (1st ed.). 260f. E=T/A, A=c-w/c+o, where T=time, A=accuracy, c=letters crossed out, w=letters wrongly crossed, o=a's omitted.

[38] Jastrow: A sorting apparatus for the study of reaction times. Psych. Rev., 1898, 5:279ff.

diameter),[39] chosen with the design of prohibiting verbal classification, which was turned thru 0°, 90°, 135°, 180°, 270°, and 315°, to make the six classes of cards to be discriminated. The labels on the compartments were so arranged as to avoid easy classification. After reading typewritten instructions[40] the reagent took a standing position at the cabinet, informed the experimenter that he was ready, and started with the experimenter's signal "go." The time of each pack was taken with a stop-watch. Introspections were written after each pack. Two packs were sorted on one day, the remaining two on another.

Efficiency consisted of the average time for the four packs in each test. The errors were very few and were fairly constant in each reagent's work.

(5) *Typewriter-Reaction*

Reactions were made with the first two fingers of the two hands to the four letters *a, t, e, n,* as they appeared automatically through a screen on the (Blickensderfer) typewriter. Reaction to one letter brought the next into view. The four series were composed of 50 letters each, so arranged that each letter preceded and succeeded itself and each other about equally often.[41] Opportunity was given for writing introspections after the 2d and 4th series. The typewriter was connected in circuit with a marker which recorded the reactions, upon a smoked drum, beside a synchronous seconds-record furnished electrically by the laboratory clock.

Efficiency was calculated from the kymograph records in seconds per series of 50 reactions. The average of the four records constituted the score of the test. Accuracy was checked by the record of reactions made by the typewriter, and since it was found to be uniformly high, it was not used to modify the time-score.[42] The four series of reactions were taken at a single sitting.

[39] See Appendix B, Figs. 1 and 2 (p. 288) for reproduction of device and arrangement of compartments in cabinet.

[40] Appendix B, Fig. 3 (p. 288).

[41] Appendix B, Fig. 4 (p. 289).

[42] No reagent made more than 3 errors; the general average was 1.6 per series.

(6) *Controlled Reaction*

Reaction was made with the first two fingers of the left hand the first three of the right hand on the typewriter. The respective fingers represented, from left to right, *Poets, Philosophers, Statesmen, Scientists,* and *Musicians.* Ten familiar names of each class[43] were arranged into 10 favorable series[44] and were pronounced singly[45]. Time was taken with a stop-watch which was selected from a collection of 10 for its favorable action. A day or two before the experiment the complete list of names was read by classes to the reagent to determine whether any were unfamiliar, and, if so, to learn them; and before the experiment he was drilled upon the class-finger coördinations until he was sure that he knew them. Introspections were written after the fifth and the last series. After the test, free reactions were taken to one-, two-, and three-syllabled names, in which all the five fingers were used, not in regular order, to determine how much variation in time might be owing to length of name.[45a] The test was taken in a single sitting.

Efficiency was calculated in terms of time alone; the mean of the 50 reaction-times, and the mean for each class.

(7) *Sound Discrimination*

Nine intervals of intensity[46] (including D=0) were given with a Wundtian sound-pendulum.[47] The upper and lower intervals could almost always be clearly cognized. The time interval between norm and variable was about three seconds, between pairs about 12 seconds, and between series of nine

[43] Appendix B, Fig. 5 (p. 289).

[44] Appendix B, Fig. 6 (p. 289).

[45] With one exception: Cr. reacted as rapidly as possible to each half of the 10 series, which was presented simultaneously to his vision.

[45a] The general averages for all reagents were: .69, .73, .81; making a difference of 0.12″ between the shortest and longest names. Since the long names were distributed throughout all series, no reference to this is made in the discussion of results.

[46] Appendix B, Fig. 7a (p. 290).

[47] Illustrated in Wundt: Grundzüge d. Physiol. Psych, I:511. Ours is the single pendulum type.

judgments 2.5 minutes. Ten series[48] constituted the test. Procedure was without knowledge and by the method of Right and Wrong cases. The reagent sat facing dark screens, with his back to the sound-pendulum which was about 5 meters distant; he recorded his judgment upon the intensity of the second sound (always the variable) by the use of symbols[49] signifying "greater," "less," "like," and "doubtful." Introspections were reached between series and after the test all of which occupied the hour.

Efficiency was calculated in terms of Right judgments and the 'Difference Limen.'

(8) *Memory of Sounds*

Five series[50] of 10 sounds each were constructed with four easily distinguishable sounds (relative intensities: 0.12, 0.8, 2.1, 5.)[51] produced on the sound pendulum. Members of a series succeeded each other at the rate of one second; an interval of 2.5 minutes was given between series. The reagent sat 5 meters from the sound-pendulum with his back toward it, and recorded the sounds in terms of 1, 2, 3, 4, in the order of their intensity. He was familiar with the sounds of the instrument since this test followed the test on Sensible discrimination, and in a preliminary practice he was drilled until he could name instantly any of the sounds produced in irregular order. The reagents recorded in ruled forms; and wrote introspections between series and after the test.[52]

Efficiency was calculated with Spearman's "Footrule for scoring the memory test."[53]

[48] Appendix B, Fig. 7b, (p. 290).
[49] Appendix B, Fig. 8, (p. 290).
[50] Appendix B, Fig. 9, (p. 290).
[51] From Fechner: Psychophysik., I. S. 181.
[52] This holds true for all the succeeding tests on memory.
[53] Whipple's Manual (1st ed.), p. 367.

$$R = \frac{d}{(n^2-1)/3}$$ which gives a perfect score of 1; the score of a correctly placed letter in a series of 10 = 0.1.

(9) *Memory of Consonants*

The consonants were printed by hand in capitals (12-14 mm. in height, strokes 5 mm. in breadth) and were clearly seen from the station of the reagent 5m. distant. The light entered the room through northern windows behind and above the reagents, and the Jastrow tachistoscope[54] was surrounded by black screens which concealed the experimenter and his manipulation of the apparatus. The test was composed of 5 series of 10 letters.[55] The letters were presented at the rate of one second, the series at the rate of two minutes.

Spearman's "Foot-rule" was used for scoring.

(10) *Memory of Numerals*

The procedure was the same as above except that digits[56] were presented instead of consonants.

(11) *Memory of Visual Signs*

Procedure was the same as in No. 9 except that meaningless optical signs[57] (suggested by and similar to those illustrated by Stratton)[58] were used instead of consonants, and the test consisted of a single series. The reagent reproduced by drawing.

(12) *Memory of Associated Pairs*

The letters of No. 9 and the digits of No. 10 were presented in pairs[59] at the rate of a pair a second, with the Jastrow tachistoscope; after an interval of 60 seconds the series of letters was shown at the rate of a letter in three seconds during which time the reagent was required to record the digit associated with the letter. The five series were separated by intervals of 2.5 minutes. The reagents were especially instructed to depend upon association alone for reproduction.

The scoring was made on the basis of 0.1 points for each correctly recorded digit.

Tests No. 8 to No. 12 were usually given in two sittings.

[54] Illustrated in Whipple's Manual (1st ed.), p. 365.
[55] Appendix B, Fig. 10a (p. 290).
[56] Appendix B, Fig. 10b (p. 290).
[57] Appendix B, Fig. 11 (p. 291).
[58] Stratton: Experimental psychology and its bearing upon culture, p. 29.
[59] Appendix B, Fig. 10c (p. 290).

(13-14) *Learning 12-Consonant-Rectangles*

Through a tachistoscope of the Wundtian type[60] rectangular cards (10.2 x 15.3 cm.) bearing three horizontal rows of 4 consonants were exposed. The letters were printed in black ink with rubber type (21 mm. high), broad Roman rather than Gothic in style[61] (lightest strokes were 1.5 mm.; broadest 4 mm. in width). The disposition of the reagents and apparatus, the condition of the light, etc., were the same as in the preceding memory tests. The letters were clear and distinct from the reagent's position. The time of the exposure was 10 seconds. It was preceded by a pre-signal, "Get ready for No.—," given 7 seconds, and a signal "ready" given 2 seconds before the screen was removed; it was succeeded by a free interval of 10 seconds which was terminated by the signal "Now," when the reagents recorded in ruled forms. The test consisted of 10 experiments, which came at the rate of 2.5 minutes. Introspections were written between experiments and after the test.

In the test with distraction, the reagents were required to add eight digits called out by the experimenter at the rate of one a second, during the 10″ interval after the exposure, and to record the sum before beginning to record the letters.

Records were scored according to the following values for a reproduced letter: 2 points for the correct line, 1 point for the correct column, making 3 points for a correctly placed letter.[62]

Tests No. 13, and 14 were given in a single sitting.

(15) *Word-Completion*

The reagent was furnished ruled paper, and a blotter to use as a screen. Then three separate columns of 10 consonants[63]

[60] Illustrated in Wundt: Grundzüge der physiologischen Psychologie (5te Auf.) 1902, Bd. III., S. 334.

[61] Appendix B, Fig. 12, (p. 291).

[62] Although this method is not satisfactory, and Cohn (*op. cit.* S. 161ff.) and Segal (*op. cit.* S. 136) justly claim that errors demand separate treatment, if a single score is to be derived for a measure of reproduction, some arbitrary method must be accepted and this one combines favorable features in the methods of Winch (Br. Jr. Psych., 1:129) and Smith (Mind, N.S. 5:52). See Appendix C, (p. 295).

[63] Appendix B, Fig. 13, (p. 291).

each were dictated to him which he recorded and covered with his screen, leaving a space of about 4 cm. between the columns. He was then told that under his screen were ten lines of three letters each, and that upon signal he was required to remove his screen and to fill in letters anywhere in order to complete a word on each line. Time was taken with a stop-watch. In case the ten words were not completed within 5 minutes, the unfinished work was taken.

(16) *Trains of Ideas*

Reagents were instructed to begin immediately from the stimulus-word and write by word or phrase as many ideas as possible within the two minutes allowed them. Three stimulus words were given: *horse, potato, flute.* Connections were then explained and the ideas counted.

Tests No. 15, and 16 were usually given in the same sitting with No. 2 and 3.

(17-18) *Extensive Threshold of Visual Attention*

The same apparatus and like material and procedure as in No. 13 were used except the exposure was about 0.1 seconds (0.085″), the free interval between exposure and reproduction was 5 seconds, and the rate of experiments was two minutes. The whole card fell within the angle of acute vision.

In the test with distraction the 5″ interval after the presentation of the card was used by the reagent for adding 4 digits pronounced at the rate of one a second. The sum was recorded before the letters.

Tests 17 and 18 were taken within the hour.

(19) *Tapping*

The reagent tapped five series of 30″ each, with intervening rests of 2.5 minutes. He used his right hand in a manner chosen after a preliminary practice; he was instructed to keep his method constant and to tap as rapidly as possible. The Morse key was sent at a tension of 50 grams, and an amplitude (at the button) of 1 mm. (approximately the adjustment preferred by telegraph operators). Records of the tapping were

taken on a kymograph beside a seconds-line furnished by the laboratory clock.

The kymograph records were scored from the time-line and the taps counted for every interval of 5 seconds. Total efficiency was found by the average of the taps per series of 30 seconds; the "Fatigue Index" was derived by dividing the average of the last five intervals of the first series by the number of taps in the first interval. All procedure was according to Wells[64] except in the use of the right hand only.

d. The Training Results

According to the design of our investigation our chief concern is with analyses of processes, their changes during training, and the factors responsible for improvement. The amount of improvement in training, the probability of the attainment of maximal efficiency, what general conditions correlate with poor and good daily averages, and what special causes of variability affected the scores, are also noticed.

(1) *Extensive Threshold of Visual Attention*

These tachistoscopic practices consisted of 25 1/10-second exposures per day of cards (4″ x 6″) bearing 12 capital consonants (21 mm. high) (See Appendix B. Fig. 12, p. 291) printed with rubber stamps evenly in three rows. Reagents sat 5 m. distant; experimenter was concealed behind the apparatus which was screened in black. The record of the reagent was made in a ruled form and was begun five seconds after the exposure was made; in scoring, a letter was evaluated three points if correctly placed, two points if misplaced in the line, one point if it appeared anywhere else. Experiments took place at the rate of 1 1/2 minutes. Introspections followed each experiment.

Three reagents, Mn., Le., and Al., took the training, the first two upon three days of the week, the latter upon successive days, at the same hour of the day, and under as nearly constant

[64] Wells: Normal performance in the tapping test. Am. Jr. Psych., 1908, 19:437ff.

conditions as possible. The extent of the training was respectively 18, 18, and 8, days; and the gain over the first day's average was respectively, 29%, 26%, and 29%.

The practice-curves indicate that maximal efficiency had probably not been reached (*vid.* Appendix B. Fig. 14, p. 291).

The day's work was not long enough to produce fatigue. Days of poor scores were days of poor control of attention, of discouragement, of thinking that maximum efficiency had been attained, of being bored by the experiment. Days of good scores were days of good attention, and the best days usually came after a week-end or a short vacation.

The process varies considerably, even during a sitting, and, although many of the factors of variability will be found in the following descriptions of changes in processes during training, some of them may be noticed here.

The degree of attention may vary from 'slack' to "wide-eyed and breathless" (Al.). The presentation may occur just before, at, or just after, the crest of the rhythm of attention. The extent of attention may be confined to a few letters, when they will be clear and the rest of the card may not be seen at all (Mn. 2:24); or it may cover the whole card in which case all imagery may be so vague as to effect a blank score, (Mn. 2:13). In the intermediate cases the attitude toward the more vague content determines whether the interval after perception is given to rote repetition of the 'clear' letters or is given in part to 'maturing' vague letters. Variability arises in the effort to coördinate the latter two processes.

The material for any reagent is not uniform: Some letters, such as form familiar initials or abbreviations, are 'significant' and may challenge apperceptive elaboration at the sacrifice of further perception, (Mn. 6:11); or they may prove more facile in apprehension and more ready for recall, (Le. 15:16). Some letters are more difficult to name (Le. 2:16, 11:8) and some groups are particularly non-euphonious (Mn. 3:7).

Among other subtle causes of variation may be mentioned an inducted effect through rapport between the experimenter and reagent, of the experimenter's variable state of alertness.

During Mn.'s 11th and Le.'s 12th day the experimenter intentionally varied the manner in which he gave the two signals ("Ready for No.—," given seven seconds before, and "Ready," given two seconds before each exposure) according to three types, (a) sharp, alert, (b) indifferent, (c) low, decisive. The averages of both reagents were lowest for the 'indifferent' type; Mn. averaged highest for the 'sharp,' and Le. for the 'low, decisive' type. The experimenter chose the last type and was thereafter careful to keep his own condition of attention more constant.

Since introspections, under the limitation of time, could not be complete, and the respective reagents differed in their selection of factors, the manner in which processes changed through the training will be noted for each of the three reagents separately.

Mn., during the habituation period of the first few days, changed from visual to a kinaesthetic retention because of the higher reproductive value of the latter. Only letters repeated by name were readily reproducible, and the period of exposure or the entertainment of the after-image was so brief as to limit naming to but a few letters: "I seemed to have the time in this case to repeat the (4) letters. I can remember the letters more readily by this process, but usually the time does not seem long enough for this" (1st day, 3d experiment).

At the beginning, when scores were relatively low, attention was usually confined to the first line, or to a part of it, often leaving all the rest of the card unnoticed: ("All the (4) letters were clear, but I didn't seem to see the rest of the card," (2:24)). At this time a whole line produced a good score, but when the score was to become larger, the extent of the attention had to be increased, and consequently its direction changed. This change was facilitated by occasional good scores from relatively indistinct impressions resulting from chance failure to direct attention (1:10); but a too diffuse attention was checked by an occasional blank score due to the imagery being too vague: "Attention on the whole card—can't recall a letter," (2:13). Attention by the 7th day came to be directed upon some other

than the top line (7: 3), and by the 12th day, since it was found that scattered letters appeared most frequently above those in clearest vision, the lower part of the card was chosen, the 3d line being favored: "Find I cannot do well at the middle line," (12: 16). But these conscious changes in method correspond to 'rests' in the practice-curve, and were not for any length of time strictly adhered to.

Not only did the spread of attention now include letters that at first could not be seen, but visual imagery was required to reproduce the additional letters, since the interval was taken up by the verbal repetition (13: 7, 15: 3). This coördination of the two kinds of imagery holding their respective content was not at first very good and never did become efficient; the letters held in the visual imagery were prone to escape before they could be recorded (3, 7: 17, 15: 5) although they sometimes returned (5: 14).

Associations of letters with familiar abbreviations, initials, names, words, etc. were not much used. Introspection notes no more than one case (2 or 3 letters) on each of the following days: 2, 6, 12, 13, 14, 15, 16. But the last two days they promised to become prominent; on the 17th 11 letters were reproduced from them, and on the 18th 15 letters. During these days they merely supplanted verbal repetition of letter-names and did not contribute to the larger scores. But had training continued, they probably would have been coördinated with the verbal and visual imagery to the end of fixing more of the impression before it got away.

The attitude toward the vague impressions changed and undoubtedly contributed toward the rise in the curve. It was not until the second day that the five-second free interval before recording was used in part for developing or defining impressions; it was customarily used in merely repeating the names of the letters that had been clearly seen. On the 3d day vague imagery began to yield letters: "The first two letters were very distinct, but I do not know how I saw the last ones: When I was recording them, I felt them rather than had an image," (3: 1); "During the interval I tried to recall the letters; and

those recorded are the letters that came, although I have no visual image to prove that they are correct" (3:6). But on the 5th day uncertified material was accepted with caution: "J (a clear letter) always seems associated with L for some reason, and the L forced itself [properly] into the record" (5:20). By the 9th day, however, this material was regularly given a chance, which was almost always warranted by the score. The following will show the character of the material:

7:8 "The impression of the three letters seemed very indistinct, but during the interval they seemed to take a definite form."

8:6 "P was particularly clear; I do not know how I got S for I cannot remember seeing it especially."

9:18 "I remember only seeing V, but during the interval the rest of the line (3 letters) was completed."

10:6 "When I repeated the letters, K and Z were the only decided ones; but during the interval the others seemed to fall into place (2 letters)."

11:4 "L and T were the only letters that were distinct. The others seemed to fall into place during the interval."

12:8 "I do not think I saw the last two letters, but in some way they came to my mind during the interval while I was repeating the others."

14:10 "I did not see the D as the third letter, but something put it there during the interval."

15:3 "I am not sure what the third letter was. When I repeated them I could get no sound in the third space; but visually it seemed to be F, although it does not seem to fit when I repeat them." (The first, second and fourth letters were clear. The third is often omitted by this reagent, and indeed also by others.)

16:5 "I had no idea of the third letter. K came when I repeated them, so I recorded it." (Correct).

16:11 "C came as a feeling; seemed to see a rounded form." (Correct).

17:8 "I got a vague idea of a number of letters, but R was the only clear one:" 4 others were correctly recalled and a P recorded in error for a B.

That this material was related to vague visual impression was indicated by an occasional error: "C and N came during the interval; N was especially insistent," (14:24). (Wrong—the two letters were G and V; similar forms).

There is a fairly good correspondence between a favorable attitude toward the indefinite impressions and the rise in the curve. Improvement was largely due to the development of vague unrecognized material into correctly recorded letters.[65] While this development was in progress there were some tendencies working against good scores: Lines distinctly seen sometimes failed to mature into letters, (8:25), and sometimes letters plainly seen failed to be named and could not be recalled (7:17).

Certain peculiarities of the individual consciousness or of the process had some effect upon the scores: Among them are: (a) the unfavorable effect of favorite or significant letters (M, X, C, Q,) (6:11, 7:9, 10:20, 4:6), through narrowing conscious-

[65] The "maturing" of a latent or subliminal impression, in tachistoscopic experimentation, has been observed by others:

The distinction between the "recalled" and the "means" of recalling, insisted upon by Cohn (Beiträge zur Kenntniss der individuellen Verschiedenheiten des Gedächtnisses. Dritter Internationaller Kongress für Psychologie, in München, 1896:456-458), involves a maturing of imagery; he says that the retained letter may be a visual image while the means to its recollection is an involuntary image in an abstract connection (p. 457), and that when it is schematic, or incomplete, it often "matures" (ergänzt sich) through reflection.

Hylan (The distribution of attention. Psych. Rev. 1903, 10:398) found that "a special effort to recognize an indistinct character would frequently cause it to mature into complete recognition before others which were at first more distinct," and that sometimes the indistinct letter would "come floating into the mind as an afterthought when all had been given that could at first be remembered." The impression of letters exposed serially (rapidly) could be held an appreciable length of time without recognizing a single letter, until each was recognized one at a time.

Bergström (Effect of changes in the time variables in memorizing, together with some discussion of the technique of memory experimentation. Am. Jr. Psych. 1907, 18:236) found that the rapid displacement of one impression by the next interferes greatly with the memorizing, and inferred that an unconscious organizing process (apperceiving or fixing) continues some time after the impression has been received, which is necessary for its permanence and revivability.

ness to them alone; (b) the persistence of impressions from former experiments; (c) the difficulty of cognizing letters of similar form, or of naming and of reproducing non-euphonious groups of letters, (3:7); and (d) the shifting of letters to fill a space occupied by an unseen intermediate (usually the third) letter. The last was largely corrected during the training through increased power to develop letters from obscure imagery.

The facts that the coördination of the two kinds of imagery (visual and kinaesthetic) was not yet perfected; that the coördination of associations with the imagery was just on the point of beginning; and that the coördination of the reproducing and the recording processes was still defective, supports the objective indication of the practice-curve that training had not yet reached maximum efficiency.

Le. changed direction of attention from the first line, when increasing score demanded more than four letters, to the middle line (7th day), and then to the blank space just above the middle line (13th day). These changes were made on the basis of the adequacy of chance variations from the usual method. Extent of attention changed from the first two letters of the first line to four; then this tendency to limit the range to clear impressions changed to include impressions of various lower grades of clearness. Intensity of attention varied from day to day and from experiment to experiment, but effort was made to keep it at maximum: "Find that fair (as distinguished from good) attention makes considerable difference; I see the card as well, but the letters are less clear, and fewer are noted"; and good scores are correlated with introspective report of good attention.

Although extent and intensity of attention, or distribution and clearness, are supposed to vary inversely, there was during the training a development of the field of maximal clearness as well as the lower levels of clearness; and there was a gradual transition from a one-level to at least a clearly eight-level or multi-level clearness of tachistoscopic impressions; the table below, which is made from introspective data, will illustrate:

Table showing eight-level clearness

The figures in the table represent the number of letters reproduced from a single exposure. The figures in the first line stand for the following headings:

1. Day and Experiment
2. Very clear
3. Clear
4. Fair
5. A little vague
6. Vague
7. Strongly suggested
8. Suggested
9. Unrecognized content

1	2	3	4	5	6	7	8	9
1:3		2						
1:5	1	2						
3:12		2	1					
14:2		1	3				1	
14:5		2	1		1			
14:16					6			
14:24	2				2		1	
15:2			5		1			
16:2		5					1	
16:3		3			1		1	
16:21	2				2		1	
17:2		4		1			1	
18:9	1	2					2	
18:11		5			1			
18:13		3			2	1		

In this selection of introspections it is seen that each consecutive level is distinguished from one or more other levels in some individual experiment.

The fringe material gives rise to imagery all the way from (a) no recognition to (b) visual recall, recognition, and reproduction of letters in their proper places; that is, apart from gradual extension of some degree of clearness into its field, there is on the van of this conquest an occasional 'maturing' of its material into correctly recorded letters:

"Had idea of other lines but not enough for recognition."

"Had strong idea of other lines but not enough for recognition."

"Had idea of other letters but could not recall."

"Saw lines but couldn't recognize letters."

"Saw whole line and noted others as containing letters—in past experiments when one line was seen nothing of other lines was noted."

"Other lines noted, a little vague to recall."

"Other letters noticed, almost recognized."

"Saw no letter clearly; all suggested by lines and made defi-

nite by repeating during the interval; not sure of any." (Good score).

"Saw lines, later recognized K."

"Partly seen and later recognized as S."

"In interval named letters in line but did not decide that I had seen R (a fifth letter) until after recording line; then had vague visual image of R." "Added C after writing line, from image."

"Image not determined until after line was recorded."

Again, the suggestion may be definite without recognizing any material as imaged; "No image, letter came with feeling of familiarity."

The way in which the boundary of clearness is extended into the territory of the unrecognizable, may be illustrated by the advance beyond the capacity of the eleventh day to apprehend clearly the four letters in the line fixated:

"Idea of other lines, but not enough for recognition."
"Stronger idea of other lines; not enough for recognition."
"Line clear, extra letter a little vague."
"Line clear, extra letter clear."
"Line clear, two extra letters vague."
"Line clear, two extra letters clear."

At first the extra letter comes as a maturing visual image, vaguely, then more clearly; then it is clear enough to be named and fixed kinaesthetically with the others.

In the very first experiments Le. held her visual image during the 5-second interval after which she named and recorded the letters. Then she named the letters during the exposure, retaining by repetition and recording from kinaesthetic imagery, occasionally receiving an extra letter from visual imagery later. But by the 6th day she gave up the moment of exposure to the vivid life of the after-image, to "Einprägung," and named the letters in the interval afterward; "Named from image one by one as would from card, but slowly." She customarily recorded from kinaesthetic imagery. During this "Einprägung" she 'felt' clear letters in her mouth, the vague letters, suggested by lines, being named for recognition afterward. If letters were not so clear, or formed non-euphonious groups the names were

repeated two or three times during the interval. The visual image of an outlying letter sometimes escaped during the process of naming the others; and when the letter was recalled more vividly for retention during the naming of the others the latter became doubtful owing to faulty coördination of the two processes.

Certain peculiarities of the reagent's process affected the score: (1) She often, especially in dull mental condition, found it difficult to name the letters (2: 11, 13, 14, 15); sometimes she was balked for several seconds (4:15, 5:11, 8:7); and sometimes she would make the best of the situation by miscalling: "Called Q 'H', holding a (corrective) visual image of Q," (4: 19). This difficulty was more prone to occur when Q, Y, or Z began the line fixated (11 : 8). An effect of the difficulty in naming was to confuse the order (5:8), in which case the letters were named in trial orders until the reagent was satisfied by a feeling of familiarity (4: 11).

(2) Certain combinations of letters flashed into significant groups which at first challenged attention to the exclusion of further perception, but later served readier apprehension; such were the initials of friends, silver-ware marks, etc.: J B, J D, T M, S K, L K, T B (Tuberculosis), S F (San Francisco), etc. W M were noticed to be similar in construction.

(3) All through the training there was occasional self-consciousness in fixating (11 : 18) resulting in (a) more or less irregular phenomena, such as winking, shifting, or squinting the eyes, just at the moment of exposure, and (b) eye fatigue and strain (11 : 19, 14: 17).

Al. used an essentially different method from the others; he endeavored to get the whole presentation, inhibiting the tendency to limit the area of attention to a smaller and clearer field.

From the 'fringe' levels, letters appeared often through kinaesthetic-auditory imagery and were correctly recorded although they were not remembered as seen; they often matured in visual imagery, generally with doubtful position; and often

letters insinuated themselves correctly into the record because they "seem to belong there," neither 'cue' nor verifying imagery being accessible to consciousness. Perhaps the general method of attending intensely to the whole card favored 'fringe' phenomena.

The fixing of letters during exposure, or while the after-image persisted, was effected by naming the letters; and kinaesthetic imagery was the customary 'cue' for reproducing and recording; sometimes the imagery was supported by visual imagery, and sometimes additional letters were visually reproduced and converted into kinaesthetic before recording.

Sometimes a "curious rivalry" between the two kinds of imagery occurred with respect to what letter belonged to a certain position, in which case records customarily followed the stronger kinaesthetic-auditory. But in some cases the position was medial between the two letters. Again, a kinaesthetic-auditory C was corrected visually to Z. Certain assimilative effects evidently resulted from the rivalry of the imagery: J seems G when the latter was just diagonally below it. Again, this assimilative effect may involve only visual factors: M seems X when the latter was just above it.

Mnemonics were avoided and very few associations involuntarily occurred.

Development consisted in more adequate control of the attention during (a) apprehension, (b) fixing, and (c) reproducing periods. (a) On the second day the reagent recorded, "Have learned to regard the card as a whole; distinguish many more letters than at first, but cannot fix them;" and of the letters distinctly seen, three introspections of the second, third, and sixth day's record: "Saw more letters distinctly than ever before," "Saw more letters, say six," "Saw more letters, say eight or nine." Particularly for the earlier part of the training, apprehension in its advance far out-distanced fixing and reproduction. (b) More visual images were named and fixed, and (c) in reproduction the reagent ceased to distrust insistent, but not perceived, letters, as persisting from some former apprehension, and became willing to give them a chance in the score.

Many letters, no doubt, through this change of attitude toward the 'fringe,' 'matured,' as is indicated above in connection with attention; at any rate the scores generally justified the record.

Further and more direct evidence of the more efficient control of the attention, noticeable through lack of strain, is given in an introspection on the 7th day: "Attention as usual, 'open-eyed,' to take in whole card, but not breathless as formerly."

Al.'s maximum daily average occurred on the 3d day (see Curve, Appendix B. Fig. 14, p. 291), and the question arises as to whether all the improvement of his training was made during the first three days of work, and therefore likely to lie in an habituation which lacks the general character requisite for transference. If there was further improvement it was such as failed to affect the scores. Were the same question to be put concerning Mn.'s training for the same length of time (8 days) the same hypothetical conclusion would result, for the first daily average to exceed her third was the ninth. Yet in the face of the gradual ascent of her practice curve up to the 18th day, the probability of improvement on the days between the 3d and the 9th can scarcely be denied.

In what then would Al.'s improvement beyond the 3d day consist?

Tabulation of letters recorded as doubtful indicates that the averages of the days following the 3d were made up more largely of 'fringe' letters and less clear letters; if we express in per cent of the average scores the amount contributed by 'fringe' letters during the course of training, we get: for the 1st and 2d days, 8%; 3d and 4th days, 4.4%; 5th and 6th days, 20%; 7th and 8th days, 17%.

The averages from which we have inferred corresponding capacity therefore represent, in part, disparate processes. And since the conquest of the 'fringe' content in consciousness was seen to be an essential part of progress in the cases of Mn. and Le. and since it has been taking place with Al. since the 3d day, it seems more than probable that improvement has continued throughout the training. This view is strengthened by the introspective notes clearly indicating increase of sensitivity,

and by the experience, common to all reagents, of confusion in reproduction of the distinct content through effort to mature further 'fringe' content. Advance has been made in apprehension; training had not continued long enough to coördinate the part-processes sufficiently for reproduction to show the gain.

For all of the reagents the effect of training was in the following points the same: (For Al., omit a, d, f, h):

(a) More letters were clearly seen,
(b) More letters were distinctly seen in less clear imagery,
(c) More 'fringe' material developed into letters,
(d) There was more efficient coöperation of kinaesthetic and visual imagery for the purpose of recall,
(e) There was less variability of attention,
(f) There was more adequate distribution of the attention to the part-elements of the process,
(g) There was greater ease, less strain, in perception, retention and reproduction,
(h) There was more apperceptive and associative process in apprehension of letters, serving a fuller content and surer recall.

(2) *Learning 12-letter-Rectangles*

Rt. and Sl. gained upon their first day's average 53% and 42%, respectively, during their 18 days of training. Maximal efficiency had not yet been reached (see practice curves, Appendix B. Fig. 15, p. 292). The daily work was not sufficient to show the influence of fatigue.

Days of low scores were: after Easter vacation, when efficient coördination of part-processes had to be built up again, for there was a reversion to earlier processes; and days of poor attention.

Rt. began learning regularly with the first line and proceeded as in reading. He got a strong visual impression and converted it into kinaesthetic-auditory imagery for retention and reproduction, repeating it during the 10-second interval. Upon the first day he began to convert the stimulus immediately into kinaesthetic-auditory imagery without reinforcing the visual impression, and when visual imagery of letters revived after they were retained and reproduced by the Kin.-aud. imagery, it was deemed

a hindrance. In case some letters were held visually after the screen had fallen they too were named and included in the repetition of kinaesthetic-auditory imagery. But when such a visually held letter was remote, in the third line, it was retained visually while repeating the other letters in kinaesthetic-auditory imagery (which by the end of the first day decreased in its auditory support) and was converted only upon recording. Up to near the end of the 2d day the few associations that occurred were also deemed a hindrance, for the letters were, like the earlier visual letters, retained kinaesthetically: "Associations annoy me." But in a few experiments an association came in a convenient place, after six kinaesthetically retained letters, and its letters were not repeated during the interval but were recorded from the visually held association. This is, in brief, the way in which visual imagery in direct form, and association, grew into value as supplementary devices to the kinaesthetic rote method of learning, the coördination of which played so great a rôle in raising scores as training proceeded.

The first appearance of the developed method was on the 2d day (16th experiment) when the first six letters were held kinaesthetically, the next two by associations (CP, chemically pure), and the next two visually; only the first six letters being repeated by rote during the 10-second interval before recording. In the first experiment of the 4th day this method recurred, the association being LB (pound). But it took the training of the 4th, 5th, and 6th days to make this the predominant method, which with favorable modifications gained in elasticity and value until the maximum scores were made.

During the period of emergence of this method, of the three-fold content, a two-fold content was dominant (see Analysis Curves, Appendix B. Fig. 16, p. 292). After the third day it was a rare score that contained only kinaesthetically held letters, although 12 out of the 3d day's 20 were such. The independent visual images of letters were held side by side with the kinaesthetic, except that the kinaesthetic were being constantly repeated during the free interval, while the visual persisted from the first reinforced impression. During this

development of the coördination of the two processes of retention and recall, a secondary visual imagery emerged, weaker than the other and often accompanied by doubt as to its value. It was imagery persisting apparently in its own strength, not having been reinforced during perception; and it often came late,—after all other letters had been recorded.

It was this last kind of visual imagery, strengthened and made more reproducible through training, which later became available when associations could not be readily formed, to prevent the learning process from lapsing into the early two-fold form. Under favorable conditions six letters were as many as could be safely held kinaesthetically, and four visually (primary), which would give a score of 30 points, and some of the daily scores exceeded this. Since coördination of the three-fold process involving associations, which became dominant on the 7th day, had resulted in carrying out the two-fold process, in experiments in which associations were not found, before the interval of exposure closed, time for strengthening the secondary visual imagery was provided.

In successful work therefore, the process became at least three-fold. On the 10th day a four-fold process appeared several times, (letters held in kinaesthetic imagery, visual associations, primary reinforced visual imagery, and secondary visual imagery).

The general method became elastic in recognizing favorable associations in other positions than in the two spaces following the 6th, to which they had heretofore been confined; i.e., the six letters to be learned by rote changed from the first six to any not available for associations. Three times on the 16th day associations fixed the first two letters, and through the later period of practice all spaces presented favorable associations.

The character of the associations seems to be largely visual; the stimulus yielding a word in visual form. It seems doubtful if many are accompanied by meaning, or at least if the meaning is prominent as it would be if the associations were apperceptive; the reagent calls them "visual" associations throughout.

Letters held in each kind of imagery sometimes escaped, and occasionally returned later in time for recording.

The method of recording passed through a development. At first it followed the order of the letters on the card. Later, the visual imagery, which under low conditions of attention faded rapidly, was recorded first, then the kinaesthetic, then associations, and last the secondary visual. The order of recording followed the increasing reproductivity of the material, except for the secondary visual imagery.

Some variable influences upon the score were apparent:

(1) If attention was not good,
  (a) Naming for kinaesthetic images was retarded,
  (b) Visual imagery was weak, and
  (c) Possible associations escaped notice;
  (d) All imagery, especially visual, faded rapidly, and sometimes escaped during the interval.
  (e) In recording, some of the imagery escaped, and the order of the letters recorded was confused.

(2) Some material was harder than others to pronounce and retarded the process.

(3) Unusual associations, especially at first, retarded the process.

(4) Since forming associations became a prominent motive in the method, material difficult to associate decreased, and material furnishing easy associations increased the score.

Improvement seems to consist in
  (a) Higher sensitivity for the visual material, since the secondary visual images developed, and moreover, into two grades of clearness.
  (b) Higher reproductivity of letter-names.
  (c) Coördinating kinaesthetic and visual processes, so as to develop from a two-fold to a four-fold content.
  (d) Greater facility in forming visual associations.
  (e) Greater facility in apportioning the letters on the card to the appropriate part-processes.
  (f) Better coördination of the recording process with the retaining process.
  (g) Better method in recording with respect to the vividness of part-contents.

(h) Possibly an increase in liability of reproduction of all imagery.
(i) Decrease in variability.

Sl. began learning by repeating the letters on the card in reading order. Upon the first day he attempted to visualize the lower row, middle row, or the top row, while he repeated by rote the other two rows which he intended to hold kinaesthetically; occasionally he sought by tense staring while naming to have visual imagery support the kinaesthetic. In the 15th experiment of that day he hit upon an association: BRQM (Laxative Bromo Quinine) and recorded LBRQ, and noted in his introspections that "It probably did not help me to remember."

The next day he tried to fix all the letters by naming, and found it too much, losing, in that experiment, all but one line. He then began his later method by confining his rote memorizing (Kinaesthetic) to the eight letters of the first two lines and held as much as possible of the third in visual imagery. In a few cases the kinaesthetic imagery of the first two lines was supported by associations: JPN (Japan) and BHSR (Belshazzar); and again WMBR (Wamba).

Upon the 3d day his visual imagery of the third row was assisted by associations (Z, last letter of the alphabet, and J his initial). Thus appeared the alternate form of his method. But it was not yet a conscious method, and was not much used until the 9th day from which time it was used to fix about as many letters in the third line as were reproduced visually. "Can repeat only names of first two rows so as to remember them; either have mnemonic for third row or visualize." A curious thing appears to have occurred during its emergence at that time, which seems rather an effect than a cause of its use. The visual imagery used during the preceding four days seemed to change to what was called in the discussion of Rt.'s results a 'secondary' form (*i.e.,* not reinforced during perception) or an apperceptive form involving alphabetic position, which related it to a class of the associations available and used at first

particularly for X and Z, as is shown by the prevalence of substitutions of near-lying letters, as H for J or K. The reagent repeatedly said he did not visualize, neither did he repeat, nor did he form those letters into associations—he "just remembered them." "Last letters written in lower row are remembered by gazing steadily at them and names are not pronounced neither are they visualized." He also records some letters from this field which he cannot account for: these are what I have called the 'secondary' visual form, when they came in the visual mode. Apparently one cause for this change in the character of his visual imagery is that as he gazes at them he is not so much intent upon sharp visualization as upon seeking mnemonic devices to fix them.

Up to this time he had made three perfect scores by holding the lower row in visual imagery. From now on, all his perfect scores (22) with one exception were assisted by associations, the first three occurring on the 9th day.

The following table shows the relative use of his three kinds of retention for the third row, the 'visualized' and the 'secondary' visual letters combined:

Day	No. of letters recorded from each Kin.	Vis.	Ass'ns
1	4	1	0
2	2	3	1
3		11	2
4		7	8
5	5	22	6
6		10	4
7		28	0
8		18	8
9	9	9	18
10		18	17
11		29	17
12		15	17
13		10	18
14		12	8
15		20	32
16		34	11
17		16	32
18		14	34

By the ninth day his method was to gaze at the 3d row during the exposure seeking a mnemonic association or visualizing while he was repeating by rote the eight letters above held in peripheral vision.

Conflict between the visual and kinaesthetic processes encouraged the search for mnemonic aids. His visual imagery was very unstable and vanished upon slight provocation. If it was to persist, it had to be made as vivid as possible during the impression; but that took attention from the rote process with the result of losing some of the kinaesthetic letters, or of losing the rhythm and sequence, which led to transposed letters in the record; then again, if effort was put disproportionately upon the kinaesthetic process, the lower row would be lost.

The associations were not used advantageously above the 3d line; in fact they were disturbing there. They often resulted in substitutions of other letters, indicating that the form of association was not visual, as in the case of Rt., but more apperceptive. Sometimes they were of a complex nature: MDKS was held by "M.D., Mark Keppel, Snell;" ZGJX, "between special letters ZX, George Jones." Sometimes letters in a well known combination would be absorbed in another more special but earlier one: PBDV gave Peabody, although since the combination had occurred before, "deo volente" had been common for DV.

The visual imagery of letters seemed to be more easily held if they were accompanied by associated letters, and the process was often thus a three-part process: Kinaesthetic for 8 letters, associative for 2, visual for 2.

A peculiarity of Sl.'s imagery was that as long as he held his eyes on the screen, after the exposure, the letters remained there; but as soon as he glanced down to the paper, they either vanished or took a position on his forehead where they were very unstable and were apt to escape while he was recording the kinaesthetic letters. It took special effort to retain them.

His other imagery was also quite unstable, for any inner distraction was fatal to it; upon one occasion he began record-

ing with the wrong letter and almost lost the whole score. He tried to hold the imagery by keeping his body rigidly in the same position. Recording was an especial distraction.

A development of the kinaesthetic process took place: At first he merely named letters "in his mind," then in a whisper, finally with very slight throat and tongue movement. The first was not vivid enough and the second was too slow.

The variable influences upon the score recorded in the discussion of Rt.'s training were present here also; except that No. 3 may be omitted and No. 4 made applicable to the 3d line only.

Improvement seems to consist in

(a) Coördination of visual, kinaesthetic, and associative processes.
(b) Using incipient pronunciation with rote process.
(c) Better apperception of visual images.
(d) Coördinating the recording and retention processes.
(e) Making association a method.
(f) Decrease of variability.

It does not seem that sensitivity to visual imagery, or that reproductivity except as better effected through (b), was increased; and the method remained fairly mechanical.

(3) *Reaction to Sound*

Ly. did not greatly reduce her reaction time by her training of 11 days, 100 reactions per day, (1.4%).

That there was a change in the process is indicated by the character of the practice curve: There was a drop down to the 6th day, showing at that point over initial capacity a gain of 19%; but from then on there was a gradual rise to almost initial efficiency.

If the ten reactions each of the 27 series, on the 100-gram tension of the key, are distributed and plotted (5 sigma to the plot) in three distribution curves of 90 cases each (corresponding curves, with 10 sigma to the plot, are shown in Appendix B., Fig. 18, p. 294), it is seen that the motor reactions with times around 100 sigma have fallen away, after the middle period;

that the highest mode has shifted from 158 in the first period to 178 in the middle and last periods; that the chief block of reactions which came, in the first, between 130 and 170 sigma, has broadened in the middle to 180; and that the last curve is cut by a cleft at the point where the first has the highest mode, giving rise to two blocks: 130-155, 160-195. The median has moved from 159 to 160 and 165.

The introspections throughout are headed "Sensorial"; at the same time, individual introspections note pressures, strains, and tensions in the fingers, hand and arm, and premonitory reactions indicate a motor direction of attention. Although the introspections are not full enough to determine definitely, yet there is some evidence that the process of reaction became less motor as practice continued, after the sixth day. It may be that as training proceeded the sensorial form was more nearly approached, yet the first considerable mode of the first curve, from 130-145, continued and broadened toward longer time, in the middle curve, has split in the last curve with the narrower mode at 130-135 and the broader at 140-155, whereas the former mode of 130-135 would seem to be the place for a practiced sensory time. The widening of this mode in the second curve, and the growth of a wide mode from 140-150 in the last, seem to indicate the development of factors in the process of reaction which (a) shifted most of the 'sensorial' reactions to 140-150, and (b) gave rise to a more frequent type of reaction at 160-195, where the last curve has its largest block of reactions and the first curve is most serrated. Introspections do not make clear what those factors are; but they must be such as cause reactions to fall central upon 148 and 178 sigma.

The process at the beginning of practice was sometimes pure motor (90-110 sigma), often sensori-motor (110-120), very often sensory (130-140), and more often a complicated sensory (145-165). During training, the motor disappeared, the sensori-motor diminished, and the practiced sensory narrowed (130-135), the sensory (135-150) became more frequent, and the

complicated sensory (160-195) most frequent. This development into longer time conforms with Bergemann's results on influence of practice on sensorial time.[66]

There was a decrease in variability, which is usually taken to indicate improvement in attention, but it is still large (MV., 13%), about 5% above practiced form (8% of the mean).

(4) *Memory Training*

He. and Cr. tested mnemonic devices for memory of figures, dates of events, and lists of words.

Although the modern[67] systems of mnemonics have the advantage of the older[68] in that they rely upon the congruence rather than the incongruence of the supplied mnemonic word or phrase, they are open to two chief criticisms: (a) They add to the material to be memorized, and (b) the supplied mnemonic is likely to be replaced by a false one (He. lost the key-word "pass-key" in the mnemonic for Homer, by substituting "latch-key", which changed the date from 907 to 567). The chief advantage of mnemonics appears to lie in the better apperception of the data to be remembered, by reason of subjecting them to especial attention in order to determine that they are correctly represented in the key-word of the mnemonic. Since the *natural* relations in the data are obviously the more profitable to be scrutinized, the advantages outweigh the disadvantages, if anywhere, only in the learning of dates, telephone numbers, street numbers, or other disconnected numbers.

That great advantage is gained by inspecting and grouping numbers, not for the purpose of transposing them into mnemonic phrases, but for noting the relations subsisting between the respective groups, was shown by the correct reproduction of series of 24 digits after grouping them into three's and inspecting them just once.

[66] Wundt: Physiologische Psychologie, III:421, (5te Auf.).

[67] *E.g.*, Harvard College—Teach much—t-ch-m-ch—1636. (*Vid.* James: Briefer Course in Psychology, p. 74; or Prin. of Psychology, vol. I, p. 669).

[68] *E.g.*, Xenophon—a-zang-for-fun might do damage with *matches*—m-tch-s—360.

The principal object of the training, however, lay in the repetition of lists of words, in conformance with Loisette's[69] instructions for the training of attention by "compelling the intellect into some particular channel and keeping it there," "by compelling the intellect to stay with the senses," through analysis of connections between words in a series and frequent rapid repetition with full concentration. He claimed to have made weak memories strong, and good ones better, by this method.

The method involved (a) an attentive apprehension (auditory or visual) of a list of words, having a more or less obvious sequence, with the view of noting the relations between each two words, and (b) an immediate recall of the whole list after the single apprehension. Later, on succeeding days, the lists were to be repeated orally from memory, forwards and backwards, as rapidly as possible, recalling clearly the relations between the words. Notes were taken of the time and errors. The reagents set for themselves three subsidiary aims: (a) to determine the advantage of scrutinizing the relations between the successive words, for reproduction after a single impression, (b) to learn whether the initial stability of the particular connections remains relatively the same in successive reproductions, and (c) to learn if the liability[70] of recall remains the same in successive reproductions, as shown by the time to reproduce the series.

The second list of 30 words began with: Building, dwelling-house, parlor, partridge, feathers, light, lighterman; the relations between the words are: genus and species, species and genus, whole and part, partial identity in sound, whole and part, substance and attribute, partial identity in sound. The list was dictated to He. by Cr. at the rate of one word per second, and was reproduced orally by He. in 160 sec. and by Cr. in 58 sec. Three lists were learned and reproductions were made on nine days after March 3d, to April 14th.

[69] Loisette: Assimilative Memory, 1896, p. 20.

[70] For the special meanings of "liability" of reproduction, and "fidelity" of reproduction, *vid.* Külpe: Outlines of Psychology, p. 197.

The chief subsidiary results may be stated as follows:

(a) Scrutinizing the words for relationships results in successive associations of continguity reinforced by a unity in meaning: *i.e.,* in the "Pointer, oak, ax, steel, ore, mine," series, Pointer, oak, are not only together in consciousness as two words, but the pointer is visually or kinaesthetically imaged as an oak pointer; and oak, ax, are unified in an image appropriating any suggested relation between them, as of cutting down the oak tree, or of fashioning the pointer; Building, dwelling, house, are imaged as separate buildings in a hamlet, bearing spatial relations to each other, and parlor and partridge are in the dwelling—they all constitute a simple 'complex'. Incentives for recall are thus doubly strong. The reagents were surprised that the process of reproduction after a single impression went off with so much facility and with so few errors.

(b) Although certain parts of a series visualized or imaged in a 'complex', fitted into a story built up through the imagery suggested by the words at the first impression, seemed to be more difficult and to demand more attention, in subsequent reproductions, than other parts, this difficulty resulted in halting the rhythm of repetition rather than in errors. The errors were almost wholly omissions, occurring in almost any part of the series, but seldom recurring in subsequent reproductions. They are caused almost wholly by incentives of recall reaching beyond the next member in the series. Introspection indicates that incentives reach from one 'complex' to another so that the most important member in the next 'complex' comes into consciousess before all the members of the last and the beginning members of the next are recalled, and that this consciousness of direction gives confidence and facilitates repetition. In this way ground is covered from one 'complex' to another by neglecting some of the intervening members. The incentives of recall of the next word constantly vary in successive repetitions. To attain accuracy intense concentration seems necessary, unless the process is to become merely rote-repetition by the vocal organs, which throughout was guarded against under the injunction of the training to "keep the intellect with the senses."

(c) The liability of recall, as shown by the time taken to reproduce the whole series, fluctuates constantly from day to day, yet considerable practice-effect was shown by both reagents, which indicates that in general liability or recall increases under conditions of relatively few repetitions during a long interval of time. If a free interval before a subsequent reproduction is but two days, the liability of recall is considerably increased, as shown by decrease in time; if four or five days, it is still increased, if 14 or 15 days, it is slightly decreased—about as much as it is increased after four or five days.

The advantage of the use of mnemonic connections in learning German-English vocabulary (*e.g.*, mistrauen—miss—shy girl—shy—diffidence) was not definitely determined; although a list of vocabulary could be repeated with certainty after one perusal, that perusal took about as much time as equally efficient direct learning; and although the former has the advantage of the use of the logical memory, while the latter relies more upon sensory memory, its connections seem to drop away with the flight of time about as rapidly as sensory memory falls away.

Concerning the principal object of the training, introspection says: "Takes intense concentration; afterwards feel tense in the frontal regions." But beyond the feeling that attention was keenly experienced in the training, and therefore presumably improved, there is no quantitative evidence at hand to show that improvement was made.

This training was not as regular nor as systematically controlled as the foregoing.

e. The Test Results

In the following discussion of test results we shall notice chiefly (1) the extent of variability in mental processes between different reagents who apply themselves to the same objective task,[71] (2) the extent of variability in a single

[71] Some of this variability will undoubtedly result from differences in 'type,' whatever that proves ultimately to be, but the following discussion takes no account of it; owing to the difficulty of diagnosing and adequately describing an individual's 'mental type,' since all individuals are probably mixed types

reagent's processes while applying himself to the same objective task, and (3) the conditions which must be met for the scores to be comparable. (4) The causes of variability, so far as they appear, and (5) the effect of variability upon the scores, are not neglected.

According to the form into which we have cast our tests and training, it must be remembered, the particular influence of training upon these tests which we are seeking is that of improved attention. The initial efficiencies of the first series of tests constitute a cross-section of the initial capacity of attention; the final series of tests gives the final capacity of attention. If the processes in the final test have changed essentially from those employed in the first test in some other way than may be attributable to better attention, if, for example, the method of work is different, then the difference between the two scores would represent something besides the change in attention, and could not be used. At best, such a difference-score could only indicate the advantage or disadvantage of doing the task in another way. Scores of the same reagent to be comparable must consequently represent similar processes; scores of different reagents to be comparable, we must assume, should also represent similar or at least equivalent processes, and score-differences, or per cent of change in efficiency, to be comparable should be based on something near equal initial efficiency.

When comparable, the difference-scores of the trained and control reagents will be inspected for transference of improved attention.

The degree of analysis in the various tests is not uniform for the reason that the processes engaged in the tests varied

which vary according to means of diagnosis (*vid.* Segal, *op. cit.* and Fernald *op. cit.*), only the following general and perhaps untrustworthy characterization of our reagents, based largely upon questionnaire replies (Wissler: *op. cit.* 8-9) supplemented by oral report, may be offered:

	Mn.	Le.	Rt.	Sl.	Ly.	He.	Cr.	Al.	Ms.	Wf.
Visual	Strong	Strong	Strong	Weak	Strong	Fair	Weak	Fair	Strong	Weak
Auditory	Good	Strong	Weak(?)	Weak	Good	Good	Good	Good	Strong	Weak
Kinaesth.	Good	Strong	Strong	Weak	Good	Good	Good	Good	Strong	Weak

greatly in complexity, and the introspections of the reagents consequently varied correspondingly in completeness; but effort is made to analyze the tests employing the less complex processes fully enough to serve our primary purpose and to contribute to the popular notion of the nature of 'mental tests.'[72] That the extent of variability may be adequately indicated, all the tests are subjected to analysis,—an analysis that is not merely a logical schematism, but an empirical construction built up from the introspections.

(1) *Reaction to Sound*

Simple Reaction Time has been used in the study of Attention (Angell and Moore,[1] Binet[2]), in determining mental and physical correlations with children (Gilbert,[3]) and with university students (Cattell,[3a] Cattell and Farrand,[5] Wissler[4]), in determining psychological norms of men and women (Thompson[6]), and in the study of individual psychology (Binet et Henri,[7] Henri[8]). The latter[8a] emphasize the value of the M.V., which has been suggester by Titchener[9] and Pillsbury[10] as a possible measure of attention, and has been denominated by Buccola "the dynamometer of the attention."[11]

[1] Angell and Moore: Reaction Time: A study in Attention and Habit. Psych. Rev. 1896. 3:245-358.

[2] Binet: Attention et Adaptation. Année Psych. 1899. 6:276ff.

[3] Gilbert: Researches on the mental and physical development of school children. Studies from Yale Psych. Lab. 1894. 2:81.

[3a] Cattell: Mental Tests and Measurements. Mind. 1890. N.S. 15:376.

[4] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon. No. 16. 1901. P. 7.

[5] Cattell and Farrand: Physical and mental measurements of the students of Columbia University. Psych. Rev. 1896. 3:639ff.

[6] Thompson: Psychological Norms in men and women. Univ. Chicago Contrib. to Phil. 1903. 4:8ff.

[7] Binet et Henri: La psychologie individuelle. Année Psych. 1895. 2:445.

[8] Henri: Étude sur le travail psychique et physique. Année Psychol. 1896. 3:245.

[8a] Also, Binet: A propos de la mesure de l'intelligence. Année Psychol. 1905. 11:69-82.

[9] Titchener: Simple Reactions. Mind. 1895. N.S. 4:79; also, Lectures on the elementary psych. of feeling and attention. 1908. P. 280.

[10] Pillsbury: Attention 1908. P. 89.

[11] Buccola: La legge del tempo nei fenomeni del pensiero. Milano. 1883. P. 155; (Quoted by Oehrn: Experimentelle Studien zur Individualpsychologie. Psych. Arbeiten. 1896. 1:113).

[72] In order to allay any suspicion that our tests are not representative and are peculiarly subject to variability in processes, a paragraph, with references, showing the relation they bear to other tests reported in the literature, is added to the discussion of the results of each test.

It is well known that intensity of attention lowers both the time[73] and the relative variation in simple reaction. But for averages to show this, they must not be influenced by other causes of variability: Health, 'Anlage,' habituation to external distraction, and the direction of the attention must remain uniform. The introspections indicate extraneous causes of variation:

(a) Conditions of health, through good, dull, tired, nervous, etc.

(b) 'Anlage', from interest to indifference, calm to anxious, natural to muscular or sensorial set of consciousness.

(c) Process, as regards habituation to external distraction (such as noise, unaccustomed finger reaction, pressure on the key, temperature of the hands); as regards fluctuation of the attention, within the series, between muscular and sensory reaction.

Another variable factor lies in the movement: In raising the finger, the extensor muscle must overcome the flexor, and owing to the balance between the tensions of these antagonistic muscles, the reaction movement is not simple but varies from a simple extensor reaction retarded by flexor tension, to an extensor reaction preceded by antagonistic flexor reaction which delays the reaction movement 40-50 sigma,[74] and three types of this variable factor have been observed.[75]

Examination of the test averages and the distribution curves confirms and supplements the evidence of introspections. Clearly, the test averages cannot be handled recklessly. They cannot be compared at random for at least four good reasons:

(a) The change in the direction of the attention within the series, as shown by a bifurcated distribution curve, and by a large mean variation, is compatible with good attention. The average of such a series might lie above or below that of a series obtained with an equal degree of attention, but where the direction of the attention remained constant: *e.g.*, The attention of Le. may have been quite as good in the series giving an

[73] Cattell: Phil. Stud. 3:329ff.; Pillsbury: Attention, 82; Külpe: Outlines, 432.

[74] Smith, W. G.; Antagonistic Reactions. Mind, 1903, 12:47-58.

[75] Judd, McAllister, and Steele: Mon. Supp. Psych. Rev, No. 29, pp. 141ff.

average of 117.2 with a mean variation of 16.6, as in the series giving 136.4 with a mean variation of 4.6; and it may have been no better.

(b) Even when the direction of the attention is constant and the psychical process is about the same for the individual reagent, his results cannot be compared with those of another reagent whose process, as shown by a widely different average time, is essentially different, for the 'abbreviated' and the 'complete' forms are not merely different forms of the same act but are different acts,[76] and practice-effect is greater upon the 'complete' than upon the 'abbreviated' type.[77]

(c) Test averages which include great practice-effect are not comparable with those which do not, for they are not so reliable a measure of efficiency.

(d) Test averages of reagents showing widely different facility also are not comparable because the reagents cannot be assumed to be doing the same work.

Were all of the variable influences to remain about the same in the final tests as they were in the first, and were the essential processes also to remain the same, for each reagent, then all the averages might be used in determining influence of the training interval. In so far as our results vary from this requirement, they have to be put aside.

Distribution curves show changes in the essential processes in the final test, for the majority of the reagents: Le. from an automatic (95 sigma) and a muscular mode (110-135) to a sensory (140); Sl. from a sensory (145) to an automatic (95) and two muscular modes (130, 115); Ly. from sensory (145-155) to automatic (100-125); Cr. from muscular (111-120) to sensori-motor (130); Ms. from less to more automatic (94-100) and muscular (125-130); Ct. to less automatic (90-105) and to more motor-sensory (144-150).

The reagents differed greatly in initial efficiency (ranging from 116.0 to 186.1), and fall, in that respect, into four groups about the following averages: 115, 130, 155, 185.

[76] Angell and Moore: Reaction Time. Psych. Rev., 1896, 3:245.
[77] Wundt: Physiologische Psychologie, 1903 (5te Auf), 3:419.

The per cents of change in the final test from the first, for the reagents whose scores are fairly comparable, are:

	Trained	1st Control[78]	2d Control
Group 2	Mn. -4.3 PE 4.38	Wf. -0.15 PE 3.40	
	He. 5.8 PE 5.62		
3	Rt. -17.0 PE 6.05		
4			Rr. -6.7 PE 20.

And these figures are not entirely free from other causes of variation besides change in processes: Those of Rt. and Rr. are too great because of the large practice-effect in their first test (Rt. 80 sigma, Rr. 40). The loss of He. resulted from the fact that his first test was taken in practiced form, just after long practice in another experiment. Wf.'s decrease of time should have been more, for at the beginning of his final test he was "rather fatigued," and for the latter part "somewhat nervous," and his first test was taken while still in practiced form from preceding experimentation.

The absolute difference for Mn. is a third larger than the probable error, for Rt. three times as large, for He. a half larger, for Wf. and Rr. much less.

In concluding our comparison we can only consider it possible that Mn. and Rt. have transferred some improvement to this test: Mn. from tachistoscopic training, and Rt. from a slight practice in simple reaction to visual stimuli if not from his training in Learning 12-letter-rectangles.

Nor with the averages for variability are the results more decisive; yet, as was noted above, they are recommended as measures of attention. This would be true, no doubt, if the measure is to include steadiness of direction as well as of intensity of attention, as was suggested by Whipple.[79] Yet, were the direction of the attention constant, it is not obvious that a given amount of variability from a 'sensorial' average is just equivalent to the same amount of variability from a 'muscular'

[78] The 1st Control reagents are those who took all the tests; the 2d Control, those who took but one pair or a few pairs of tests.

[79] Whipple: Reaction Times as a test of Mental Ability. Am. Jr. Psych., 1904, 15:496.

average, even when both averages are made by the same reagent;[80] much less when made by different reagents. On these grounds then, the variation averages of all those who changed in the form of their reaction, in the final test, must be disregarded, which leaves the following:

	Trained		1st Control		2d Control	
	MV	r.v.	MV	r.v.		
Group 2	Mn. -4.7	-5.1	Wf. 2.7	1.9		
	He. 0	-0.9				
Group 3	Rt. -1.7	0.9				
Group 4					Rr. -10.8	-3.8

The r.v. = MV/M x 100,[81] and makes the figures somewhat more comparable than without the reduction.

Variation in initial relative variability ranged from 8.0 to 18.8. The increase of Wf. is due in part to his low variation in the first test, taken when he was in practiced form, and in part to nervousness and exhaustion in the final; the decrease of Mn. and Rr. is principally due to better habituation to experimental conditions, Mn. possibly bringing some advantage from her training with the tachistoscope. Part of Rr.'s great decrease must be attributed to his extreme nervousness in the first test (his first Avg. MV was 45.9, while Mn.'s was 17.5).

It is evident that in the reaction-time experiment the reagent must, as Wundt claims, be "thoroughly practiced in the technique," or "there can be no hope of obtaining reliable results;"[82] and that lack of expertness in introspection makes it difficult to group the processes according to kind, so that they may be measured and their measurements justly compared. It is claimed that some reagents are so incapable of control of the direction of their attention that they cannot be used in the experiment.[83] As to the effect of practice on variability, it has been shown under certain conditions to increase it.[84]

[80] *Vid.* Alechsieff: Phil. Stud., 1900, 16:24.
[81] Titchener: Experimental Psychology, 1905, II, I:182.
[82] Wundt: Vorlesungen, 1911 (5te Auf.), S 312.
[83] Lange: Phil. Stud., 1888, 4:479.
[84] Angell and Moore: Reaction Time, Psych. Rev., 1896, 3:245-258.

(2) *Marking Out Small* a's

The discriminative reaction of "Cancellation" was commended by Pillsbury[1] as probably the best test of the positive type for measuring attention. It has been recommended and used for this purpose in almost all of the important studies in individual psychology (Binet et Henri,[2] Henri,[3] Toulouse,[4] Oehrn,[5] Binet,[6] Sharp,[7] Whitley,[8]); it has been used as a mental test in correlational studies (Cattell and Farrand,[9] Wissler,[10] Brown,[11]), as a means of studying the processes of recognition and discrimination (Bourdon,[12] who originated the test), attention and adaptation (Binet[13]), fatigue (Ritter[14]), habit (Bourdon[15]), distraction and habituation (Vogt[16]), general practice effect upon like or related processes (Thorndike and Woodworth,[17] our own experiment on marking out words, pp. 34ff), practice effect upon individual differences (Wells,[18] Hollingworth[19]); and it is included in Whipple's Manual[20] with tests for "Attention and Perception," where an historical and descriptive account of the test may be found. One letter or character may be crossed out, as the small *a*, (Bourdon,[12] Binet et Henri,[2] Toulouse,[4] Sharp,[7] Whitley[8]) or more than one letter, as *a, e, l, t,* or *a, e, d, r, s,* etc., wherever they occur (Binet[6] [13] Ritter,[14] Bourdon,[15] Vogt,[16] Brown,[11]), or words which contain given letters, as both *e* and *r,* may be crossed out (Thorndike and Woodworth[17] and our own experiment, pp. 34ff). The matter containing the letters to be cancelled may be ordinary printed text or printed mixed words, in a known or in an unknown language, printed pages from printer's "pi," small letters or capitals, pages of spaced or unspaced digits, *etc.*

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[1] Pillsbury: Attention. 1908. Pp. 84ff.
[2] Binet et Henri: La psychologie individuelle. Année Psych. 1895. 2:446.
[3] Henri: Étude sur le Travail psychique et physique. Année Psych. 1896. 3:239.
[4] Toulouse: Enquête medico-psychologique sur les rapports de la supériorité intellectuelle avec la névropathie. (Zola) 1896. P. 226.
[5] Oehrn: Experimentelle studien zur Individualpsychologie. Psych. Arbeiten. 1896. 1:98.
[6] Binet: L'Étude experimentale de l'intelligence. Paris. 1903. Pp. 236ff.
[7] Sharp: Individual psychology: A study in psychological method. Am. Jr. Psych. 1899. 10:356.
[8] Whitley: An empirical study of certain tests for individual differences. Archives of Psychol. 1911. No. 19. 3:114.
[9] Cattell and Farrand: Physical and mental measurements of the students of Columbia University. Psych. Rev. 1896. 3:641.
[10] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon., No. 16. 1901. 3:7.
[11] Brown: Some experimental results in correlation of mental abilities. Br. Jr. Psych. 1910. 3:297.
[12] Bourdon: Observations comparatives sur la reconnaissance, la discrimination, et l'association. Rev. Philos. 1895. 40:167.
[13] Binet: Attention et adaptation. Année Psych. 1899. 6:364.
[14] Ritter: Ermüdungsmessungen. Zeits. f. Psychol. 1900. 24:424.
[15] Bourdon: Recherches sur l'habitude. Année Psychol. 1901. 8:330.

Marking out small *a*'s from lines of English print, 93 mm. long, on a page containing 100 of them (see p. 75), is a fairly simple task, but, as introspections show, may involve quite dissimilar processes:

(a) Movement along the line may be like that in reading, may alternate in direction, may embrace more than one line at a time, may be interfered with or facilitated by following a pencil-point.

(b) The essential process may be (1) a search for the form among all the letters, without a unit of material to search through, or with the word or the line as a unit, (2) a search for the sound-image of the letter by pronouncing the words in inner speech, (3) an incipient pronunciation of all the words with the reliance mainly upon the kinaesthetic image of the sounded letter, (4) a reading of the text and reacting upon the words known to contain *a*.

(c) The main process may not be pure, and may be supplemented by (1) elimination of words and suffixes known not to contain *a;* (2) by activity of attention in peripheral vision so as to command a larger field, leading to inaccuracy in reaching too far forward and to accuracy in catching omitted letters in the lines above.

(d) The process may be retarded by distractions such as (1) difficulty with the pen, (2) appeal of the context, (3) looking back to catch possible omissions, etc.

These various processes may be employed singly, in combination, or in succession by a single reagent in a single test; which is sufficient warning that the averages of such tests may not be used for comparison unless similarity of processes yielding them is assured.[85]

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[16] Vogt: Ueber Ablenkbarkeit und Gewöhnungsfähigkeit. Psych. Arbeiten, 1899-1901. 3:73.

[17] Thorndike and Woodworth: The influence of improvement in one mental function upon the efficiency of other functions. Psych. Rev. 1901. 8:553.

[18] Wells: The relation of practice to individual differences. Am. Jr. Psych. 1912. 23:77.

[19] Hollingworth: Individual differences before, during, and after practice. Psych. Rev. 1914. 21:3.

[20] Whipple: Manual of mental and physical tests. 1910. Test, 26, pp. 254ff.

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[85] Peters (Aufmerksamkeit und Reizschwelle: Versuch zur Messung der Aufmerksamkeitskonzentration. Archiv. f. ges. Psych. 1906. 8:391) thinks

Ly. used the visual cue; Mn., Sl., and An. reacted to *a* by an auditory image of the word; Al., Le., He., and Wf., to the word as known to contain *a*, supplemented by the visual cue. Methods changed some, or were of mixed type, for all reagents during the test. For reagents who differed in kind of performance, the averages are not strictly comparable; and for those whose process changed in its dominant elements, in their final test, the average difference-scores express something more than the effect of the training or the interval upon this test, and must be disregarded:

Rt., in his final test, added to his method of attending to words as units and searching for the visual form, direct reaction to the word without search; Cr. changed from the kinaesthetic-auditory cue to the visual cue; Ms. from the visual cue, supported by a kinaesthetic-auditory image, to the word cue; Cl., from marking words known to contain *a*, without notice of context, to reading the text; and Ly., from the word unit to reading the text. These changes in method are independent of the influence of training in sustained attention, and were as often disadvantageous as advantageous.

Initial efficiencies ranged from 113-282 seconds, and fall into six groups: 113, 129, 145, 165, 190, 280.

The more comparable scores yield the following per cent of improvement (decrease in time of 100 reactions) in the final test:

	Trained	1st Control	2d Control
Group 1	He. 9		
Group 3		Wf. 10	
Group 4	Le. 14 Sl. 9		
Group 5	Mn. 29 Al. 15		
Group 6			An. 11.3

It seems probable that the practice-effect of the test on itself is about 10%; that it was benefited by the tachistoscopic training about 10% more, but that it was not benefited by training in reaction to sound, Learning 12-letter-rectangles, or by Memory

the process so complex that it must be analyzed before any part of it can be subjected to measurement; for this reason he did not use this test.

Training, or by the other tests in the series. The quick perception of capitals in the tachistoscopic training presumably lowered sensitivity for visual impressions, or shortened cognition-time, which was available for more ready perception of small *a*'s in the text.

(3) *Marking Out Small o's*

Marking out small *o*'s from an *inverted* page of English print containing 100 (see p. 75) of them, was intended to be a process somewhat free from the distraction of the context,[86] which attended the preceding test, and to offer opportunity for a still more simple process, not so capable of change. But introspections proved it to be also quite variable.

(a) (As above).

(b) The essential process may be 1) a search through all the letters for the visual form, without a unit or with the word or the line unit, and with a purely visual image of the *o* or the visual image strongly supported by an auditory or a kinaesthetic image of it; and the kinaesthetic image may be that of a) repeated pronunciation of the name of the letter, b) breathing its sound continuously, or c) pen-movement in tracing its form; 2) a search along the line for the only natural letter, since its form alone is not altered by inverting the page; 3) a blocking of the inverted page into units of a line, or a part of a line, and a 'spotting' of the letter that 'stands out' from its surroundings, (in which case, at moments when the central preparation for its cognition was not perfected by the attention, the *o*

[86] Other methods of avoiding the distraction of the text were noted above; such as, the use of text in unfamiliar language, of unspaced or "pied" material, *etc.* Woodworth and Wells (Association Tests. Psych. Rev. Mon. 1911. v. 13, No. 5, pp. 24ff.), Wells (*op. cit.*), and Hollingworth (*op. cit.*), used digits, which appear to be much the best material yet proposed. The first two researches involved the cancellation of zero's,—a close approach to the present test. Woodworth and Wells (p. 28) note some of the irrelevant individual differences obvious to the experimenter upon examination of the checked page, or upon observation of the performance: variation in the manner of making the cancelling stroke, reversal of direction in inspection of the line, misunderstanding instructions as to amount to be checked over, *etc.*

failed to "stick out in relief from the general blur of letters" and either had to be painstakingly searched for, or its omission risked, either case causing retardation or distraction).

(c) The essential process may be supplemented by: 1) reacting to words recognized as containing *o*, 2) reading inverted words in the search for the auditory or the kinaesthetic image, 3) the elimination, without search, of words or suffixes known not to contain *o*.

(d) The process may be retarded by peculiar distractions: 1) Confusion with inverted *c*, 2) perseverence of tendency to react to *a*'s (this test followed marking out *a*'s),[87] 3) looking back for omissions, 4) tendency to turn the head and eyes to read, 5) recognition of inverted words.

The following reagents changed their processes essentially in the final test: Mn. changed from the visual cue to word-reaction supplemented by looking "for the most natural letter"; Le. changed from one or two words as a unit, to a whole line; He. changed in part to word-reaction; Ms. from inverted image of the word to visual cue and reaction to small words.

Among the other reagents the methods differed somewhat: Wf., Ly., and Al. used the visual cue and reacted to small words; Rt. skipped words and endings known not to contain *o;* Cr. and Sl., and possibly Gl. and An., used the visual cue simply. The more comparable results, because the methods are more nearly equivalent, range in initial efficiency from 125-380 seconds, and fall into four groups: 125, 190, 225, 380. Changes in efficiency are as follows, in per cent of improvement:

	Trained	1st Control	2d Control
Group 1	Cr. 0		
Group 2	Al. 13 Rt. 13 Sl. 3	Wf. 17	
Group 3	Ly. 4		Gl. 4
Group 4			An. 22.4

Disregarding the results of the 2d Control reagent in Group 4, whose initial efficiency was but half that of Group 2, it appears

[87] Binet (Attention et adaptation, *loc. cit.*) found interference in changing from *a, e, d, r, s* to *i, o, l, f, t,* (p. 370).

reasonable to expect about 5% improvement in practice-effect of the test itself; and perhaps 10% more as the result of training on the tachistoscope; none from the other tests or training. Rt.'s gain is largely due to increased facility in recognizing small words and suffixes known not to contain *o* and passing them by; there is no introspective evidence upon which to explain Wf.'s gain, but it is probably due, in part, to change in process. Those reagents who changed processes in the final test show loss more often than gain.

(4) *Card-Sorting*

Card-sorting, a series of reactions with the mental processes of discrimination of the stimulus and the choice of the appropriate movement interpolated between stimulus and reaction, has been used to determine the influence of mental work upon rate of tapping (Dresslar[1]), to learn the conditions of mental activity (Bergström[2]), to investigate the influence of interference of associations upon memory (Bergström[3]) and upon the practice-effect in forming associations (Bergström[4] and Brown [4a]) to determine the effect of mental type on interference of motor habits (McMein and Washburn[5]), to test mental ability (Bagley,[6] Burt[7]), to test motor ability (Thompson[8]), and to study the learning process in relation to transference and interference (Kline and Owens[9]). In the last research ordinary playing cards were sorted into 52 compartments, but usually the stimuli consist of letters (Bergström[2]), nonsense syllables (McMein and Washburn), words (Bergström[4]) pictures (Bergström[4]), or colors (Burt, Thompson, our own experiment on pp. 50ff.); the number of compartments, 4 (McMein and Washburn, Thompson), 5 (Burt), 6 (McMein and Washburn, and our own experiment, pp. 50ff.), 8 (McMein and Washburn), 10 (Bergström), 12 (McMein and Washburn); the packs contain 10 cards of each stimulus, except those of Bergström which contained 80 cards, and our own (see pp. 75f.) which contained 50.

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[1] Dresslar: Some influences which affect rapidity of voluntary movements. Am. Jr. Psych. 1892. 4:514ff.

[2] Bergström: Experimental study of some of the conditions of mental activity. Am. Jr. Psych. 1893-4. 6:247.

[3] Bergström: Experiments upon physiological memory by means of the interference of associations. Am. Jr. Psych. 1892-3. 5:256ff.

[4] Bergström: Relation of the interference to the practice effect of an association. Am. Jr. Psych. 1893-4. 6:433ff.

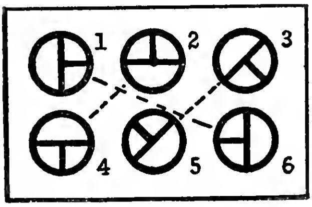
[4a] Brown: Habit interference in sorting cards. Univ. Calif. Pub. in Psych. 1914. Vol. I, No. 4.

[5] McMein and Washburn: Effect of mental type on the interference of motor habits. Am. Jr. Psych. 1909. 20:282ff.

[6] Bagley: On the correlation of mental and motor ability in school children. Am. Jr. Psych. 1900-1. 12:195.

Reaction with discrimination and choice is probably more variable in its processes, in the work of the same reagent as well as in the work of different reagents, than is simple reaction, since there is more psychial process interpolated between the stimulus and the movement, and variability in reaction experiments varies directly with the amount of interpolated process.[88] But the variability may be such that two scores still belong to the same kind of act as is not the case in simple reaction when one of them is of the muscular and the other is of the sensorial type. Yet even here the scores may also be incomparable because the acts are different in kind.

Each pack of fifty cards in this experiment was made up of six symbols shown in the accompanying plate of the compartments according to which arrangement they were distributed (see Appendix B. Figs. 1, 2, p. 288).



In the cognition of the smybol, the diameter was seen by Cr. and Wf. as classifying the cards into vertical, horizontal, and oblique, pairs; by others as merely forming the base of a pointer. The radius was accepted as a pointer by all, except Ly., who named the location of the filled half of the circle, and He., who named the location of the blank half, and was interpreted as pointing right or in, left or in, up or out, down or out, down-oblique or slant down, and up-oblique or slant up; Ly. and He. used the same terms of direction. The cognition of the symbol was especially difficult for Ly.

These terms of direction served to locate the three pairs on the cabinet, in the scheme shown above by the connecting lines,

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[7] Burt: Experimental tests on general intelligence. Br. Jr. Psych. 1909. 3:136.

[8] Thompson: Psychological norms in men and women. Univ. Chicago Contrib. to Phil. 1903. 4: No. 1. 15.

[9] Kline and Owens: Preliminary report of a study in the learning process, involving feeling tone, transference, and interference. Psych. Rev. 1913. 20:206ff.

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[88] *Vid.* Külpe: Outlines, 422; Oehrn: Psychol. Arbeiten, 1:131-2; Alechsieff: Phil. Stud. 16:24.

for most of the reagents (Mn. Le. Rt. Ly. He. Cr. Wf. Dn.) before the first test was over; Sl., Ms., and Fr., differed, in that the latter two had formed no scheme in the first test, and the former merely formed a mnemonic device to hold the two rows; as, upper row has two radii East and one North, lower row has two West and one South (map directions), without further placing of either pairs or single cards.

Individual variation in the process of distributing was considerable.[89] As is indicated above there were some marked differences in the main outlines of recognizing the symbols and of forming a scheme of the compartments. But even where the main outlines were similar, great variation obtained in the detail of the development in the course of the tests, so that, strictly speaking, no two averages are measurements of precisely the same mental processes. This variation consists in

(a) Differences in the predominant imagery (verbal, visual, kinaesthetic) used in cognition of the symbol and in locating its compartment; in consequent variation in the number of steps in placing a single card (as, 1—visual impression of the card, 2—verbal image accompanying its cognition, 3—visual or verbal image of the compartment, 4—kinaesthetic image of movement of arm to that compartent, 5—visual impression of the compartment, 6—impulse of movement; or, merely steps 1, 3 and 6).

(b) Varying dependency of the imagery used as a cue for the movement, upon a definite memorial scheme of the compartments, or upon random memorial elements of preceding sortings.

(c) Relative adaptability of the scheme adopted (Sl.'s was particularly unwieldy).

(d) Facility in perfecting the scheme.

(e) Facility in superseding it with automatic coördinations.

On account of these individual variations in the process of distributing, at any given point in the tests, not only did the schemes differ in detail, between the individual reagents, but they varied in degree of completion, resulting in varying amounts of primitive and mechanical matching of cards and labels, or in varying amounts of spontaneous sorting from perfected or

[89] *C.f.* Individual variation reported by McMein and Washburn (*op. cit.* p. 283).

from automatic coördinations. Some reagents (Mn. Dn. He. Cr. Wf.) developed a scheme early, and had the process partly automatic before the fourth pack of the first test was sorted; others (Sl. Ms.) did not get a scheme well developed at all, or only at the end of the first test (Fr.).

Many other individual variations in processes could be noticed; such as, (a) effect of sequence upon placing a card—one reagent prefers the succeeding card to belong to the same pair (Cr.); another prefers any other (Rt.); (b) relative preference for the three pairs—to one the oblique is easiest (Rt.), to another it is the hardest (Ly.), etc.

Besides variation in the process, there were variations among the influences upon it:

(a) Emotional—The sorting was vexing and disliked (Mn.), or disagreeable (He.), caused nausea and trembling (Ly.), or was interesting (Le., Wf.), or agreeable (Cr. Sl.), or indifferent (Rt.), and each effect contributed toward the attitude with which the reagent came to the experiment.

(b) The anxiety for speed varied.

(c) Physical causes—such as, "sticking of cards" (Mn.), or stiffness of cold hands (Wf.).

(d) Conditions of health—Ly., He., Cr., were fatigued for their final test, and Wf. was nervous; and Rt. and Al. were less alert than usual.

Since it is our interest to compare averages of tests separated by a long interval of training or of rest, still other variations are of great importance: Those resulting from the different degrees of reproduction, in the final test, of the schemes or of the coördinations formed in the first test. Some of the reagents (Ly., Al., Fr., Wf.) had them well in mind and could use them early in the final test; others (Le., Rt., Sl., He., Cr.) had practically to begin anew, recovering the effects of their former experience in varying degrees and at varying points in the final tests; and with both classes there was variation in respect to further development, particularly on the part of the latter. whose developments occasionally conflicted with returning details of earlier processes. The combined practice of both tests

was not sufficient to lead to automatic coördinations to any considerable degree, and all averages include practice-effect.

The development of processes through practice in the tests may be illustrated by the following record from the introspections of Cr.:

First Test

Pack 1. Matched cards with labels of the compartments continually. No compartments placed; pairs of symbols becoming distinguished.

Pack 2. Some cards distributed from memory of position from distributions recently made; some from a developing scheme of the compartments, which is now drawn from memory (correctly) with some hesitation: The compartments are grouped in pairs (according to the dotted lines in the plate a few pages back) determined by the direction of the diameters: Pair 1. (positions 1 and 6) Are verticles and occupy the opposite corners; radii in. Pair 2. (positions 2 and 4) Horizontals; oblique pair to the left; radii out. Pair 3. (positions 3 and 5) Obliques; oblique pair to the right; radii difficult, but such that I may classify "middles up" (referring to positions 2 and 5).

Continuity of attention to the process and deliberately holding the parts of the developing scheme constituted a persevering 'anlage.'

Pack. 3. Worked the scheme in about tenth the time; sorted some by exclusion; *e.g.,* horizontals belong to compartments 2 and 4; have a horizontal in hand, match with 4 and throw it into 2 without looking at the latter's label; but the process is almost wholly matching.

Pack 4. Scheme comes easier; though instead of working outright without matching, it simply facilitates matching. About an eighth of the time it works adequately alone.

Final introspection. Chief hindrance to the sorting is losing calm control of the partial application of the scheme and of its extension. This does not seem to depend so much upon the intensity of the attention (which the process seems to keep high) as upon its distribution so that the memorial factors are kept sufficiently in process, which is very difficult; matching is easier. Some strain, mental and in left hand. Rather agreeable. (3 errors in the 200).

Final Test

Pack 1. Recognize symbols as familiar, but had to work up scheme of cabinet; some old classification returns, but new organization begins to supplement it: Pair 1 (positions 1, 6) "In"; Pair 2 (positions 2, 4) "Up" and "down"; Pair 3. Contrary, "Down" and "up." But must glance at the cabinet continually to assure myself of correctness of compartment.

Pack 2. Scheme did not develop so satisfactorily as it promised; for at first the process did not require glancing at the case; then had to glance to avoid having to wait on memory, which resulted in confusion to the memorial element and a resort to matching. (Best principle would have been to depend upon memory, even at occasional loss of time, thus avoiding confusion and retaining scheme). Application of scheme isn't simple: sometimes mechanical conception of direction, sometimes incipient naming according to scheme, sometimes simply matching.

(The change in Pair 2. from "Outs" to "up" and "down" resulted in erroneous application of "in" to them, causing 2 errors.)

Pack 3. (Tired; have had a wearing day.) Scheme in early part of series took on the following simplification: Pair 1. (position 1, 4) "in"; Pair 2. (positions 2, 5) "up"; Pair 3. (positions 3, 6) "down." But after working a short time it failed, and I was compelled to resort to matching. (Probably because of conflict with the old pairs, and lack of energy in holding memorial elements firm).

Pack 4. Scheme worked better; I depended upon it. Feel that I could make great headway in the next few packs, for the scheme is not fully mastered, but during this pack it developed rapidly. Instead of the old incipient pronunciation of the class-word, the cards are placed by a more facile cue: kinaesthetic imagery of the meaning of the class-word.

No consciousness of any influence of training (on memory schemes).

In spite of all the degrees of variation between the different reagents, the general experience was similar—reaction with discrimination and choice—and, since almost all reagents developed or used the same methods in the final test that they developed in the first, their results may, with reservations made obvious by the above discussion, be compared. The results of

two reagents are disregarded: those of Wf. and Fr., control reagents because of Wf.'s "mental practice" on the test, and Fr.'s review of the compartments and the perfecting of a scheme, between tests, when they should have had no practice.[90]

Initial efficiencies ranged from 79.0-105.4 seconds per 50 reactions, and they fall into four groups around averages of 80, 87, 95, and 105 sec.

The results of the reagents who maintained and developed their old methods, in per cent of decrease in time, are:

	Regular	1st Control	2d Control
Group 1	He. 23	Ms. 10	Dn. 13
	Le. 12		
Group 2.	Mn. 22		
Group 3.	Rt. 15		
	Ly. 21		
	Cr. 22		
	Al. 27		
Group 4.	Sl. 4		

The more important variations affecting these figures are: Le. took her last half of the final test 14 days after the first half, which deprives it of the practice-effect shown by the other reagents who took their's two days after. The interval between the first and final tests was much shorter for Al., which no doubt contributed somewhat to his improvement; on the other hand he was less alert than in the first test. Rt. complained of a "muddy" attention in the final. Sl.'s scheme (map directions) was so unwieldy that in his final test his efficiency fell back to its initial position and he had to cover again the ground he had covered in his first test; this is one illustration of the fact that greater "room for improvement" cannot always be predicated upon low initial capacity (his was the lowest in the series).[90a]

From the table it appears probable that 10% improvement may be expected in this test as a result of practice-effect upon itself;[91] that 10% more was contributed by the training on other material.

[90] Mental practice was shown by Johnson (Experiments on Motor Education. Studies from the Yale Psych. Lab. 1902. 10:87) to facilitate simple reaction to sound.

[90a] On this matter, see footnote 139, pp. 222-3.

[91] This supposition is supported by the evidence afforded by the former

The principal factors of improvement seem to be:

(a) A more automatic use of the memorial elements of the old method from the beginning (Al., Ly.) or soon after the beginning (Mn., Le., Rt., He., Cr.) of the final test.

(b) Some further development of the old scheme (Al., Cr.), although in this there was conflict between the new and old elements.

(c) A readier apprehension of the symbol (Ly., for whom it had been particularly difficult.)

The manner in which training affected the test is a matter of hypothesis and might be offered as follows:

The training on the tachistoscope heightened sensitivity for visual impressions, applicable to cognition of the cards; all the training in unequal degrees heightened reproductivity of imagery, applicable to the memorial elements of the scheme; the tachistoscopic training and the learning of 12-letter-rectangles exercised coördination of part-processes, applicable to coördinating discrimination and reaction; the training on the memory schemes exercised the continuous attention and the reproduction of memorial elements, demanded in this test, and all training involved habituation to distraction which would be applicable here.

A few applications of former experience may be noted as examples of transference and spread of training: Mn. and Wf. were students of higher mathematics; they were assisted immediately to the formation of a scheme by reason of the perceived relations of the radii; in contrast to this, Le. did not notice until the fourth pack of her first test that the radius formed a right-angle with the diameter on the oblique pair of symbols, which relation was then of assistance to her. Sl. brought his unwieldly scheme from the class-room.

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training in Card-Sorting (see Table XXV in Appendix A); in which, although it was probably benefited by preceding training in Typewriter-Reaction, the practice-effect of the first four packs upon the second four was, in per cent of improvement,

Cl. 0 Al. 17 Cr. 12 Bs. 5

The second four packs were distributed the next day after the first four by Cl. and Al., three days after by Cr., and in the same hour by Bs. Al., Cr., and Bs., are Al., Cr., and Ms. of the present experiment.

(5) *Typewriter Reaction*

Typewriter-reaction (see p. 76) engages the same essential processes as card-sorting, its chief difference lying in more apparatus and in the necessary changes in forms of stimuli and movements. This form of reaction was used by Bair[1] in the study of the practice curve and interference, and in our own experiment on "Reaction with Discrimination and Choice" (pp. 50ff); it was selected as a type of mental work by Seashore[2] for the convenient measurement of which he devised a special apparatus—The Psychergograph.

This test involved but four coördinations of stimuli and reactions, and thus permitted a more rapid reaction, a slower practice-effect,[92] and a greater degree of automatization, by the end of the final test, than was possible in the card-sorting test.

The order of the letters, from left to right, was *a-t-c-n*. The cognition of the letter as it appeared was not merely a perception of the letter, but an apperception of it as belonging to a certain position, to a certain key, or to a certain finger. This process varied considerably in its dominant imagery:

(a) Visual purely (Rt., He., Cr.).
(b) Sound image 1) of the phonetic value, or 2) of the name of the letter.
(c) Kinaesthetic image of the letter's sound or name (Le. Ly. Wf.); or of the movement of the eye toward its position (Wf.).
(d) Combination of the above, usually accompanied by actual incipient movement of the vocal organs in pronouncing the sound or the name of the letter, or movement of the eye or arm and fingers in locating the letter.

The placing of the letter necessary for carrying out its appropriate reaction usually involved a mechanism of some sort serviceable for keeping the order of the letters clearly in mind and the reaction to each ready. This also varied greatly:

(a) Continual repetition, in inner speech, of the letters in

[1] Bair: The practice curve: A study in the formation of habits. Psych. Rev. Mon., 1902. 5: No. 2.
[2] Seashore: A method of measuring mental work: The psychergograph. Univ. of Iowa Studies in Psych. 1902. 3:1-17.

[92] The average time of the initial 50 reactions in card-sorting was 106 seconds; in the typewriter-reaction, 50 sec. The average practice-effect in the first test in the former was 32%; in the latter, 14%.

their order (Sl. Mn.), sometimes assisted by a mnemonic device, as "Aetna" (Ly.).

(b) Classification of the letters, to hold their positions without repeating them in their order:

1) Left, a-t; right, e-n (Rt.).
2) 1, 2, 3, 4; vowels odd; consonants even (Mn.) or vowels left, consonants, right, and alphabetic extremes on the left hand (Wf.).
3) Terminals a—n; t belongs to a; e to n (Le.).
4) Alphabetic order of a-t, of e-n, and of a-e (Wf.).

The position referred to the keys (Le., Rt., Sl., Ly., Wf., Dr.) or to the fingers (He., Cr., Wf. 2); in case it referred to the former, the finger was sometimes removed and the key glanced at to verify a judgment or to restore the order of the letters to the memory (Ly., Sl., Wf.).

Besides the foregoing causes for variation in the results, there were some others peculiar to the task:

(a) Anticipation caused premonitory reactions which resulted in errors and confusion (Le., Ly., He., Sn.); the same effect is caused by rapid rhythm when the process has become largely automatic (He. Cr.).

(b) Those who formed coördinations with the keys, often had difficulty in the control of their fingers (Le., Ly., Wf., Dr.); the difficulty also occurred when the scheme paired the letters into right and left groups and operated through kinaesthetic imagery in the arms, while the order of the letters in each group was determined by visual imagery (Rt.).

(c) The mental tension involved, sometimes produced dizziness and nausea (Ly.).

(d) The action and noise of the typewriter is so different from the type-bar machines that it was very distracting to some of the reagents who were typists (Rt., Sl., He.).

As a result of the influences of these factors of variation, the task was performed in many different ways by the respective reagents; and the essential method sometimes changed during the tests of the individual reagents.

The former gave rise to, and may be said to be indicated by, great variation in initial ability, ranging from 36.4-67.7 seconds,

which shows a preference for three types: one at 40 seconds per 50 reactions (Mn., Rt., He., Cr., Ms.); the second at 55 seconds (He., Wf., Sn., Dn.); and the third at 65 (Sl., Ly.).

If the change in the individual reagent's work occurs in an early series of his first test, it lowers his average for that test and decreases the difference between the results of the two tests; if it occurs early in his final test or late in the first test it operates in the opposite direction. The change is sufficiently radical in the case of two reagents to throw out their results: Mn. changed from repetition of the series of letters, in the beginning of her final test, to the use of a classification; Wf., at the beginning of his final test, changed from "verbal image—key" to "verbal image—finger," made a radical change in method, and just before taking the final test took up practice in typewriting.

The improvement, in per cent of decrease in time, made by the other reagents was:

	Regular	1st Control	2d Control
Group 1.	Le. 14.6	Ms. -07	
	Rt. 12.4		
	He. -6.1		
	Cr. 4.9		
Group 2.			Sn. 13.9
			Dr. 13.6
Group 3.	Sl. 10.4		
	Ly. 4.7		

Since the reagents in groups 2 and 3 did not attain in their practice in the two tests an efficiency equal to that of the reagents in Group 1 at their beginning, inspection of results will have to be limited largely to the latter.

As to the practice-effect of the test upon itself for Group 2, it must be about 14%; we have, unfortunately, no trained reagents whose results can be used in comparison to test training-effect. For Group 1, however, we are able to make an estimate. From the data of the old investigation (see Appendix A, Tables XXI p. 275 and XXIII p. 276). It is calculated that continuous practice in work identical with this test, for reagents whose initial efficiencies place them in Group 1, resulted in a loss of 7% (Cl.) and 10% (Cr.), and a gain of 0.4%

(Mn.); and the effect of a free interval[93] of 45 days, after practice on 36 series, was a gain of 4.4% (Mn.). Since our practice in the first test amounted to but 4 series, and the interval was twice as long, it is possible that Le. Rt. and Cr. were benefited from 4% to 10% by their training.

This benefit could be described, however, only in general terms: (a) The coördinations became more nearly equal in strength, as is shown by decrease of the smaller variations; (b) Steadiness of attention increased, as is shown by decrease in the number of 'balks,' (except for Cr., for whom there was increased distraction in operating the recording apparatus); and (c) Control of the memorial element increased, as is shown by the decrease in the length of the 'balks.' (a) is shared by Mn., Sl., and Ly.; (b) by Sl.; and (c) by none of the other reagents. The training of the tachistoscope may have contributed higher sensitivity for the visual stimuli and better control in distributing the attention over part-processes; and the training on memory schemes may have contributed something toward better control of the memorial element.

What distinguishes the three types, as intimated above, are differences in the performance of the task: Group 1 begins with a fairly direct coördination of either visual impression, or the sound or kinaesthetic image into which it is converted, and the key or the finger; and reactions early begin to become more or less automatic (Rt., He., Cr., Ms.). The first effect of practice is likely to be loss in efficiency, as recorded in a preceding paragraph, due to evolving a scheme, more or less simple, which is to be instrumental, if practice is continued long enough, in effecting automatic coördination of visual impression and impulse of finger. Rt. began with (1) visual impression, (2) Kinaesthetic image of movement in the right or left arm, (3) visual image of key, (4) impulse of finger, and dropped (2) and (3). Cr. began with (1) visual impression, (2) verbal image, (3) impulse of finger, and dropped (2). Schemes were

[93] The effect of the 80-day interval upon all our reagents was an average loss between the last series of the first test and the first series of the final test, of 6% of the initial capacity.

very simple, relating the stimulus to kinaesthesis of arm or fingers; for Cr. this consisted in 'feeling' the letter in the finger. There was no alphabetic, logical, or phonetic classification.

Group 2 begins with a more indirect coördination of stimulus and reaction, by interpolating retarding accompaniments of cognition and a more or less elaborate or complex classification of the letters, or an inefficient memorial representation of them, so that the reacting process is circuitous. Wf. began with (1) visual impression, (2) verbal image, (3) kinaesthetic image of eye-movement to key, (4) impulse of finger, and dropped (3). Schemes were complex, alphabetic, phonetic, and logical.

Group 3 adds to these interpolations some especially inefficient process, probably usually of method. Sl. and Ly. matched letter and key, for which the reacting finger had to be removed and returned before the movement could be carried out. The process is divided into two distinct acts: cognition of letters and searching for keys.

The elements constituting the process of any reagent are at first selected from his stock of experience, and then are changed in accordance with the reagent's adaptability. No doubt Ly., who was not especially slow in card-sorting, came to the test with a strong sensory set of consciousness in accordance with her training in reaction to sound, for she complained that she gave her chief attention to the stimulus and could not get it directed upon the keys: the location of the key was either observed or remembered after its use was called for. Improvement was made, and many of the reactions were later carried out without involving a glance at the key, but the choice of the reaction remained a more or less distinct act following the discrimination of the stimulus.

Although the course of practice varied with the type, the general effect involved (a) the reduction of the interpolated process, (b) the simplification and finally transcendence of the scheme, (c) increase in partly or fully automatic reactions. The end of continued practice would be the automatic coördina-

tion of visual impression and finger impulse, into which all types would merge.

(6) *Controlled Reaction*

The Controlled Reaction involves further interpolated mental process between stimulus and reaction, namely the referring of the stimulus to one of the classes which determines the choice of the reacting movement. It has been used in Jastrow's[1] laboratory under the name of "Classification Time"; 10 monosyllablic words of each of the three grammatic classes, nouns, verbs, and adjectives, were used in irregular order as stimuli. Our test (see p. 77) follows Münsterberg[2] in using as stimuli the names of poets, philosophers, statesmen, scientists, and musicians. Both of these researches, however, used the chronoscope for measuring the individual reactions, while we used the stop-watch (except in the case of Cr. who reacted as rapidly as possible to the successive stimuli).

In this reaction there were five coördinations between class-name and fingers, but the class-name could be got only by classifying the stimulus; as, Newton, "scientist—4th finger"; Mozart, "musician—fifth finger"; *etc.*

The variability of processes may be indicated by the following classification of methods:

(a) The auditory impression of the name may be followed by a kinaesthetic image of the movement in the appropriate finger for the class to which the name belongs; and, as a result of practice, by a kinaesthetic impression from incipient movement in the finger, and later by the impulse of the finger in reaction. Attention is mainly upon classifying the name, and, at first, upon reviewing the class-finger coördinations. The coördination may be effected by conferring the professional air, disposition, or attitude of the class upon the finger (Cr.).

(b) Or the auditory impression of the name may be followed by the pronunciation of the class-name, in the effort of classification; then a judgment determining the class; then a choice of the appropriate finger; then the impulse of the finger (Ly.).

(c) The coördinations may be more or less strong so that the attention may be given to the classification (Mn., Le., Sl., He., Le., Re.); or the coördinations may be weak and demand most of the attention (Rt., He., Ms.); or both may be equally

[1] Jastrow, Morehouse, & Harper: Classification Time. Am. Jr. Psych. 1891. 4:411-415.

[2] Münsterberg: Beiträge für experimentelle Psychologie. 1889. Heft 1:85.

difficult so that the attention oscillates between more or less separate acts (Ly.); or both may be equally easy so that the attention by quick oscillations can carry them both along at the same time (Cr.).

(d) The coördination may involve a scheme of the classes on the fingers (Le.) or in the positions the fingers occupy (Rt.), or the classes may be simply held in sequential order (Wf.).

The interval between series, or between reactions, may be used in reviewing the coördinations (Wf., He., Ey.), or in keeping the mind clear, in order to avoid anticipation of classes (Ey.).

Some further intimation of the variability of the processes, not only between different reagents, but with the same reagent, (as attention must oscillate from one weak part to another of the complex process) is given by the nature of the errors. They appear to have been owing to at least four principal causes:

(a) False classification through their ignorance or confusion (Mn., Ly., He., Sl., Ey.).

(b) Coördination may be weak and the wrong finger be unconsciously used (Mn., Sl., Ly., Ms.), or confused with another (Wf.).

(c) Control of the fingers may be at fault; especially likely with the corresponding fingers of the two hands (Le., Rt., Ms., Ey.).

(d) Automatic reactions may take place before classification is made, sometimes following the pronunciation of a class-name in trying to classify the man (Le.), sometimes as a result of strong expectation for a certain class (Ey.), or of a rhythm too fast to control (Mn., Ms.).

(e) A few errors occurred through misunderstanding the name, as, Hayden for Hegel, Coe for Poe, Verdi for Virgil, (Sl., Ms.).

The greatest number of errors were made by those who put their attention mostly upon classification.

Among the reagents there was considerable variation in initial capacity; it ranged from 1.34-2.44 seconds per reaction, for 50 reactions, and falls into three groups: 1.4 (Mn., Ms., Wf.); 1.7 (Rt., Sl., Ly., He., Cr., Ey.); 2.1 (Le., Re.).

Analysis of results and examination of introspections, how-

ever, do not reveal any simple characterization for the respective groups. That they are valid is attested by the 'reduced' time (total time minus free reaction, or cognition time), which would change but two reagents, by putting Rt. in group 1 and Ly. between Groups 1 and 2.[94]

The improvement in per cent of decrease in time was:

	Trained	1st Control	2d Control
Group 1.	Mn. 19	Ms. -7.0	
		Wf. 1.8	
Group 2.	Cr. 14		Ey. 6.7
	He. 11.5		
	Rt. 11		
	Sl. 1.5		
	Ly. -5.6		
Group 3.	Le 26		Re. 20.8

Mn. and Wf. gained slightly, and Ey. considerably (7-16) in errors; the latter owing to her classification of unknown men as scientists, the least known class.

If the processes in the respective groups can be considered equivalent, and equally susceptible to improvement, some advantage of training may be presumed from the tachistoscopic, and memory, training and from learning 12-letter-rectangles. In what way the training may be presumed to influence the test is a matter of conjecture: The training on the tachistoscope and learning 12-letter-rectangles demanded keen attention upon signal for a short time, and required its distribution over the part-processes involved; the former, and also the latter in the case of Rt., heightened reproductivity of imagery. The memory training may have contributed to steadiness in keeping the memorial element of the process ready to the end of forming automatic coördinations between class and finger.

Improvement consisted in abridgement of the interpolated processes between stimulus and reaction. Some of the specific elements in this were: (a) reduction of the pronunciation of the class-word to a kinaesthetic image, or at least to incipient

[94] This is due to the fact that they took a disproportionate time for the mechanical and perceptive part of the reaction; the average was .6 or .7 sec., and they took .97 and .99, respectively.

movement (Mn.), or even to the professional air of the class the attitude of which is coördinated with the finger (Cr.); (b) effecting coördination between class and finger by use of a scheme; Rt. put poets and musicians on the ends, statesmen in the middle, and philosophers and scientists in the intervening spaces, holding the scheme visually; then the scheme became more kinaesthetic and less conscious; (c) the habit of using the intervals between series for reviewing the coördinations so as to be about equally prepared for all classes (He.), or particularly for those which have not been recently reacted to (Wf.); or for keeping the mind clear so as not to be influenced by expectation (Ey.); (d) attention steadied over the whole process so as to keep it under better control (He., Cr.).

Those who fared worse in the final test than the rest gave their attention to the classification mostly, which left the coördinations relatively free from practice-effect. Ms. lost some on all the classes, but most on poets, scientists and musicians; Sl. and Ly. made gains on poets, scientists and musicians, but lost disproportionately on philosophers and statesmen, that is, their coördinations became more unequal in strength than they had been in the first test.

None gained equally on all classes, and the greatest inequalities of gain were made by Le. who reduced her time almost wholly upon philosophers and scientists, classes that had taken on the average more than twice the time required for the other classes. But the effect of the interval on all those who gained much was to even up the strength of the various coördinations.

(7) *Sound Discrimination*

Sensible discrimination ranks with reaction time as a device or procedure in the psychological laboratory for the study of mental processes. Külpe[1] notes its high dependence upon attention, Titchener[2] suggests it as a gross measure of attention, and Spearman[3] concluded, from correlational data, that it is most closely related to general intelligence. In the laboratory it has been used in the study of memory of lengths of lines (Hegelmaier[4]), of memory and recognition of tones (pitch) (Wolfe,[5] Angell and Harwood,[6] Angell[7]), of intensities of sounds (Lehmann,[8] Angell[9]), and of shades of gray (Lehmann,[10] Angell[11]); and for the analytical study of mental imagery (Bent-

ley,[12] Whipple[13]). It has been used as a mental test in determining power to discriminate differences in pitch (Gilbert,[14] Seashore,[15] Wissler,[16] Thompson,[17] Spearman,[3] Krueger and Spearman,[18] Burt[19]), shades of gray, (Thompson[17] and our own test on pp. 42ff.) and color (Bennett[20]). The test is standardized in Whipple's manual,[21] which gives an account of its use and its results. Since qualitative variability in performance may depend in its concrete aspects upon the nature of the differences to be discriminated, it must be remembered that our test (see pp. 77f.) involves differences in intensity.

Since an analysis of the various processes of this test has already been made in a former experiment on Discrimination,[95] and a characterization of individual performances is more

[1] Külpe: Outlines of Psychology. 1901. 38, 429.
[2] Titchener: Lectures on the elementary psychology of feeling and attention. 1908. 279.
[3] Spearman: "General Intelligence" objectively determined and measured. Am. Jr. Psych. 1904. 15:279.
[4] Hegelmaier, in Vierordt's laboratory about 1852 (Quoted by Bergström: Am. Jr. Psych. 18:211).
[5] Wolfe: Untersuchungen über das Tongedächtniss. Phil. Stud. 1886. 3:534ff.
[6] Angell and Harwood: Experiments on discrimination of clangs for different intervals of time. I. Am. Jr. Psych. 1899-1900. 11:67ff.
[7] Angell: Discrimination of clangs for different intervals of time. II. Am. Jr. Psych. 1900-1901. 12:58ff.
[8] Lehmann: Kritische und experimentelle Studien über das Wiedererkennen. Phil. Stud. 1892. 7:204ff.
[9] Angell: On Judgments of "Like" in discrimination experiments. Am. Jr. Psych. 1907. 356ff.
[10] Lehmann: Ueber Wiedererkennen. Phil. Stud. 1889. 5:96ff.
[11] Angell: Discrimination of shades of gray for different intervals of time. Phil. Stud. 1902. 19:1-21.
[12] Bentley: Memory image and its qualitative fidelity. Am. Jr. Psych. 1899. 11:1-48.
[13] Whipple: An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych. 1901. 12:409ff, and 1902. 13:219ff.
[14] Gilbert: Experiments on the musical sensitiveness of school children. Studies from Yale Psych. Lab. 1893. 1:80-87.
[15] Seashore: Hearing ability and discriminative ability for pitch. Univ. of Iowa Studies in Psych. 1899. 2:55-64.
[16] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon. 1901. 3: No. 6.
[17] Thompson: Psychological norms in men and women: Univ. Chicago Contrib. to Phil. 1903. 4: No. 1. Pp. 72, 81.
[18] Krueger and Spearman: Die Korrelation zwischen verschiedenen geistigen Leistungsfähigkeiten. Zeits. f. Psych. 1907. 44:87.
[19] Burt: Experimental tests of general intelligence. Br. Jr. Psych. 1909. 3:98, 123.
[20] Bennett: Formal discipline. 1907. P. 59.
[21] Whipple: Manual of mental and physical tests. 1910. Of brightness, 159; of pitch, 180.

[95] Pp. 47f.

minutely made in a following experiment in which sensible discrimination constituted the training,[96] only sufficient analysis is made here to indicate the fact of variation in processes.

(a) The sounds may be naïvely compared as external events (Mn., Vg.) sometimes accompanied by visual imagery of the experimenter's production of the sound; as, imaging him striking the desk with a pencil; and the weaker sound may be imaged as coming from a nearer source.

(b) The image of the first may be compared with the sensation of the second (Mn., Rt., He.).

(c) The effect of the sounds on the body may be compared; as, the placing of the kinaesthetic auditory image higher or lower in the head (Le.), or the blinking of the eyes (Ly.).

(d) The reactions to the sounds may be compared; as, movements of the hands, head, throat and tongue (Ly), nodding the head (Mn.), or breathing out forcibly like an axeman when striking the blow (He.).[97]

(e) Or there may be no imagery, and the effects in the attitude compared (Rt., Wf.).

(f) And the sounds may be represented by verbal classification (Ly., Ms.).

Certain method may be employed; as, holding the breath and closing the eyes (Le.), holding the ear in a certain position to catch the sound (Sl.), making allowance for the second sound seeming relatively louder because of its getting closer attention (He.), or because it is accented by an iambic rhythm (Wr.).

The process further varied because of certain distractions; as, external noises (noted by almost all reagents), distracting thought (Wf.), difference in quality of sounds (He.), expectation (Rt., Le.). (Many noticed the difference in quality of loud and weak sounds as appearing high or low in pitch, metallic or wooden, but did not consider it a distraction except in judging "like"—Mn., Rt., Ly., He., Ms.).

[96] Pp. 199ff., 206ff.

[97] Kuhlmann (On the Analysis of Auditory Memory Consciousness. Am. Jr. Psych. 1909. 20: 194ff.) found the motor processes used in imitating the sounds to be the most frequent factor in the recall of details of sounds of familiar things.

That the essential process itself varies with the individual reagent is indicated by introspective notes that the norm varied in intensity (Rt., Ms.).

Some variation undoubtedly occurred by reason of unfamiliarity with the (customary) symbols used in recording the judgments (Le., Ms.), (*vid.* Appendix B. Fig. 8, p. 290).

Although the processes varied with each individual, there is not sufficient introspective evidence at hand to indicate any radical change between the final and the first tests.

Initial capacity ranged from 43%-73% of right judgments, and may be distributed in three groups:[98] 70% (He., Wf., Sl.), 57% (Mn., Le., Rt., Ms.), and 45% (Ly., Vg., Wr.).

Improvement made in per cent of initial capacity was:

	Regular	1st Control	2d Control
Group 1.	*Sl. 18 65 51	Wf. -4 -6 -46	
	He. 0 0 0		
Group 2.	Mn. 41 50 50	*Ms. 5 22 46	
	Le. -10 -5 -58		
	*Rt. 9 14 35		
Group 3.	Ly. 23 25 26		Vg. 30 35 37
			Wr. 25 21 21

* Foot-note 98 indicates that these reagents fall into lower classes, for the 2d and 3d columns.

The first column of per cents refers to judgments on all four intervals above and below the value of the norm, where D = 0; the second column, to judgments on the first two intervals above and below the value of the norm only; the third column to change in the "Difference Limen."

[98] The initial capacity to judge differences between the stimuli of the first two intervals above and below the value of the norm, also varies, from 29% to 58% R cases, and would also classify the reagents into three groups around the averages of 53%, 43%, and 34%. But it would change Sl. to the 2d group, and Ms. and Rt. to the 3d group.

Also the "Difference Limen" (that point between 0 and 4 intervals from the value of the norm at which 50% of the judgments are right) of the reagents ranges from 0.97 to 3.20; and classifies the reagents into three groups just as capacity of discrimination on the two intervals above and below does; except that it places Ms. between Groups 2 and 3. (These three groups: 1.2, 1.7, 3.)

About Group 1 nothing can be said except that initial capacity was remarkably high and perhaps no improvement could be expected. Group 2 shows several consistent gains: Mn. in the three columns and Sl. in the 2d and 3d columns. Abstracting from the results of Group 3, where gain should be relatively greater, Mn. and Sl. seem to have been benefited by their training. Mn. was exercised on minimal stimuli in the field of vision, and may be expected to show some profit from it in discrimination; and both Mn. and Sl. may have applied some training-effect in better attention for the moment, and in better reproduction of imagery.

Le.'s results are peculiarly clouded. They do not show the improvement she made in discrimination, for, although half of her series in the first test yielded 4 R cases each, and half of her series in the final test yielded 6 R cases each, for some reason which her introspections fail to explain, a fifth of the latter yielded but 2 R cases each. It is possible that the erasures in her record indicate confusion of symbols; in which case her irregular results are accounted for.

(8) *Memory of Sounds*

The memory span, which is found by noting the longest series of digits or letters perfectly reproduced from a single presentation, usually auditory, is noted by Pillsbury[1] as one of the customary measures of attention, and Külpe says that "attention produces its maximal effect in the reproductory sphere."[2] Our tests in memory of serially presented members differ from the memory-span test in measuring the average number of members reproduced from a single presentation of a series too long to be completely retained (Methode der behaltenen Glieder, see p. 142). This test of memory of sounds (see p. 78) follows Fracker,[3] and involves the perception and recall of four easily distinguishable intensities of sound. It is known that cognition of intensities of sensations occupies longer time than cognition of qualities, and that discrimination of intensities of sound is peculiarly difficult (Külpe[4]). These facts in addition to the novelty of the task and to the composite character of the auditory image for clangs, as found by Whipple,[5] are calculated, in spite of the simplicity of the stimuli, to cause great qualitative variation in the processes used in the test.

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[1] Pillsbury: Attention. 1908. 84ff.
[2] Külpe: Outlines of psychology. 1901. 430.
[3] Fracker: On the transference of training in memory. Psych. Rev. Mon. 1908. Whole No. 38. Experiment III, pp. 59f.

The four intensities making up the series of ten sounds were identified by the numbers from 1 to 4, in the order of intensity.

Since this test closely resembles one of Fracker's,[99] the analysis of processes and the description of methods used by the various reagents will be of particular interest. His reagents used visual imagery mainly; some of ours used neither auditory nor visual imagery (Wf.).

As the sounds came they had to be cognized, which was done by naming (giving them the numbers 1-4), or by comparing them with each other; the former needed a memory of absolute intensity, and the latter had to be done very quickly, in process, or it had to be left till the whole series had been received. These three methods of receiving the impressions would from the beginning of the experiment necessitate quite different processes, and they were all illustrated by the reagents in this test.

The retention of the sounds was carried out in various ways:

(a) Retained in auditory imagery (He.).

1) The last few sounds of the series only (Le., Ly.).
2) In rhythm according to intensity, like chimes (Mn. Gl.).

(b) Retained by kinaesthetic (Wf.), kinaesthetic-auditory (Al., Sl., Ty.), auditory-visual (Ly., Rt.) imagery of the name (number) given to the sound when it came.

1) Giving a rhythm to the naming (Le., Ms.).
2) Grouping the numbers (Le., Rt., He., Ms., Wf.).
3) Using mnemonic aids; as assigning the sounds to a spatial scheme, like numbered steps (Al.),[100] or associating their numbers with the visible numbers beside the blank spaces for the record (Sl., Ms.).

(c) Retained by kinaesthetic imagery of the response to the sounds (Ly.).

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[4] Külpe: *op. cit.* pp. 417-8.

[5] Whipple: An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych. 1902. 13:259.

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[99] *Op. cit.* Nine Tones, p. 59.

[100] A favorite method with Fracker's reagents (*op. cit.*, 70-71); Kuhlmann (On the analysis of auditory memory consciousness. Am. Jr. Psych. 1909. 20:194ff.) found visual imagery that accompanied the auditory imagery a frequent means of recall of sounds of familiar things.

The imagery of some of the reagents was of a mixed type (Rt.), and methods varied radically both between and with individual reagents.

As a consequence of doing so many different tasks in taking the same test, the results varied greatly; initial capacity ranged from .3 to .7 average points per series, and fall into four groups of about .7, .5, .4, and .3 points.

Improvement for the reagents who did not radically change their methods between tests, in per cent of initial capacity, was:

	Regular	1st Control	2d Control
Group 1.			Gl. -17.6
Group 3.	Le. 37 Rt. 38		
Group 4.	Al. 52		

Each of these reagents named the sounds as they came; for Le. the first group of four stood out in kinaesthetic imagery, the last two persisted in auditory imagery; but in the very last of the final test a new and more adequate method began to develop—retention of the rhythm of the intensities of the sounds in a series as in chimes. Rt. grouped the names in rhythms and recalled through kinaesthetic and auditory-visual imagery of the names. Al. recalled through kinaesthetic-auditory imagery; his visual imagery is not strong or he probably would have made use of the vague spatial scheme that occurred to him near the end of the first test.

Some of the other reagents made much more loss or gain (Group 1. He. –11, Sl. –3; Group 2. Ly. –16, Ms. 14; Group 3. Wf. 49, Group 4. Mn. 116%), but they all made radical changes in their methods in the final test. Mn., who made the greatest gain, grouped the sounds into three rhythms (4, 4, 2) in the first test; but in the final followed the sounds as in a tune which gave the effect of chimes, the strains of which were remembered and transposed into numbers by comparison after the whole series was received. Sl. simply named the sounds in the first test, but appealed to mnemonic aids in the final, and, for some series, associated the names of the sounds with the visible numbers of their respective spaces on the blank record before him

(the same method that Ms. used in her first and had to change from, when discovered, in her final test) or he associated them with his fingers. Ly., in the first test, reproduced from auditory and visual images of the names of the sounds, except for the last two or three sounds in the series which persisted in auditory imagery, but in the final test she used more kinaesthetic-auditory imagery for the early part of the series and kinaesthtic imagery of response to the sounds for the later members of the series. He., who found it extremely difficult in the first test to (a) name the sound, (b) place its order, and (c) hear the next one, in almost simultaneous process, and who combined kinaesthetic imagery of names with auditory imagery of sounds, gave up, in the final test, the triple process and attempted to get an auditory impression of the whole series, making identification afterward by comparison; and while he stopped in the series with as many members as he thought he could retain, in the first test, in the final he tried for all, which resulted in indefinite grouping and fixing of the members. Wf. introduced in his final test rhythms of three.

The changes that were made in the processes seem to be broadly adaptive, and in no way dependent upon the training during the interval.

The reagents in the table above had practice in fixing and reproducing kinaesthetic and visual imagery of letters, and it is possible (a) that they did not change to other methods because their training improved them in the elements they had already used; and (b) that this improvement accounts largely for the improvement shown in the table. But since there are no comparable records from control reagents at hand, the latter point must be left an open question.

The changes in method were not necessarily beneficial; as is shown several paragraphs above, in parenthesis; half of the reagents making them lost in efficiency.

As to the effectiveness of the respective methods, those who associated the number assigned to the sounds with the numbers of the blank spaces for the record made the largest scores,

Ms. producing a perfect score. The next efficient method was the auditory reception and retention of the whole series as chimes. Neither method involved the memory of sound intensity: The first being merely the memory of associated numbers; the latter, of relations between intensities grouped in a very exceptional manner.

It would seem that the visual forms of imagery employed with greatest success by Fracker's reagents were not necessary forms, but were preferences on the part of reagents who had good visual or kinaesthetic imagery, readily adaptable to the test, and encouraged by the training.

(9) *Memory of Consonants*

Memory for letters, usually consonants orally presented in a series too long to be reproduced from a single presentation (according to Ebbinghaus'[1] Methode der behaltenen Glieder), has been frequently used in mental tests (Jacobs,[1a] Münsterberg,[2] Cattell,[3] Toulouse,[4] Pohlmann,[5] Winch,[6] Bergstrom[6a] Sleight[7]). Our test (see p. 79) is similar to Whipple's Test 38 A. (2), Variation (6).[8] The five series of 10 consonants were presented visually with a Jastrow Tachistoscope.

The following is a classification of the more important methods followed by the reagents in this test:

(a) Attention to the series as a whole with the view of retaining the visual imagery (Al., who recalled, however, from auditory imagery).

(b) Naming the letters in rhythms of 4, 4, 2, (Le., Ms); of two's (Le.); of 4, 3, 3, etc.

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[1] Ebbinghaus: Ueber neue Methode zur Prüfung geistiger Fähigkeiten und ihre Anwendung bei Schulkindern. Zeits. f. Psych. 1897. 13:401ff.

[1a] Jacobs: Experiments on "prehension." Mind. 1887 [o.s.] 12:75ff.

[2] Münsterberg: Beiträge zur Experimentellen Psychologie. Heft 4. 1892. S. 121ff.

[3] Cattell: Mental tests and measurements. Mind. 1890. 15:377.

[4] Toulouse: Enquête medico-psychologique sur les rapports de la supériorité intellectuelle avec la névropathie. (Zola). 1896. 207.

[5] Pohlmann: Experimentelle Beiträge zur Lehre vom Gedächtnis. Berlin. 1906.

[6] Winch: Immediate memory in school children. II Auditory. Br. Jr. Psych. 1906. 2:52ff.

[6a] Bergström: Effect of changes in the time variables in memorizing, together with some discussion of the technique of memory experimentation. Am. Jr. Psych. 1907. 18:206ff.

[7] Sleight: Memory and formal training. Br. Jr. Psych. 1911. 4:430.

[8] Whipple: Manual of mental and physical tests. 1910. 366.

1) "Impressing" the letter-names vividly while perceiving.
2) Strengthening the kinaesthetic impressions by serial repetition after each impression (Tn., Ds.), or in groups of four (Mn.)[101]

(c) Forming associations between the letters through familiar initials, abbreviations, cattle-brands, chemical compounds, etc. (Ms., Ly., He.).

(d) Making syllables by interpolating vowel sounds (Ds.).

Reproduction usually involved several kinds of imagery in each record; usually the first part was reproduced by kinaesthetic or kinaesthetic-auditory imagery, or representative imagery (associations), and the last few letters by kinaesthetic or visual imagery; occasionally there was reproduction from auditory imagery (Ly., Al.). In case both parts of the series (beginning and end) were reproduced from kinaesthetic imagery, the former was the rote effect of repetitions and the latter the recently converted impression.

Some of the reagents changed their methods in the final test: Le. changed from a rhythm of four to a rhythm of two in naming; and in her final recorded the last group, which was not accorded so much attention, first, leaving effort free to retain the earlier part of the series in kinaesthetic imagery; and it is impossible to determine whether the disadvantage of the former change is equivalent to the advantage of the latter. Ms., though not consistent in method in either test, made some use of associating letters with their preceding fellows, already recorded, in the first test, but in the final made use of a rhythm of 4 in naming. Wf., who relied in the first test upon kinaesthetic imagery for the main part of a series and visual imagery for the last few letters, made great use of associations for the former and kinaesthetic for the latter, in the final test. Ds. changed from forming syllables by interpolating vowels, in the first part of the series, and a visual retention of the last few letters, to rapid repetitions between exposures, of all the letters from the beginning of each half of the series; as, C, CV, CVJ, CVJB, etc.

[101] *Cf.* Müller, G. E.: Zur Analyse der Gedächtnistätigkeit und des Vorstellungsverlaufes. Zeitschr. f. Psych. 1911. Erg.-Bd. 5. S. 214.

There was some variation between the reagents who retained about the same methods for their final test that they used in their first. Mn. repeated in groups of four, reviewing after each group, recalling from kinaesthetic-auditory imagery, and occasionally recorded from the bottom up (perhaps from visual imagery). Rt. divided each series into two parts for rhythm, in the first test taking 5 members for the first group and in the final 6, which was recorded from kinaesthetic imagery, and recording the last few letters in the series from visual imagery. Sl. recorded the last letter from visual, the others from kinaesthetic imagery and associations. Ly. made use of associations and reproduced from kinaesthetic-auditory imagery and from visual imagery. He. occasionally recorded the last letter from visual imagery, but most of the reproduction was from kinaesthetic imagery supported by associations. Cr. depended chiefly upon kinaesthetic-auditory imagery for all but the last two letters, which were retained visually; associations occurred occasionally. Al. tried to grasp the series as a whole, evidently a predominantly visual effort, and recorded largely from auditory imagery, as is shown by confusion between similarly sounding letters. Tn. repeated letters in intervals between exposures, each time from the beginning, until repetition excluded perception (at about the 7th consonant); then got the last few letters from kinaesthetic imagery from a single repetition.

Initial capacity ranged from .3 to .7 points, per series, and classifies the reagents into four groups: .7, .6, .4, .3.

Improvement in per cent of increase over initial efficiency, was made by those reagents retaining in the final test the methods used in the first, as follows:

	Regular		1st Control	2d Control	
Group 1.	He.	17			
	Cr.	-13*			
Group 2.	Mn.	34			
	Rt.	20		Tn.	1
	Sl.	12			
Group 3.	Ly.	-3			
Group 4.	Al.	99			

*Irregular: due to operator's error.

Were one to consider Ly. as equivalent to a control reagent, since she was training in reaction time, it would give some slender basis for supposing that He., Mn., Rt., and Al. were benefited by their training. The training of all, except He., was upon the reproduction of letters exposed as visual impressions. Rt. shows some carrying over of method in the 6-term grouping in his final test. The factors of improvement in this test are not so different from the factors of improvement in the training:

(a) Better coördination of the part-processes; *e.g.*, perceiving and naming, grasping in rhythm, reviewing a rhythmic group hastily before fixing the next; recording and retaining, since recording involves kinaesthetic reproduction of different rhythm, also an accentuation of the group attended to, at the expense of other groups retained kinaesthetically. This contributes toward the following classes, but does not account wholly for them.

(b) Better fixing of imagery.

(c) Better recall.

The last two factors depend upon increased sensitivity and higher liability and fidelity of reproduction. Both are affected by conditions of attention.

The complete segregation of these factors is not possible with the present data, though each is occasionally clear. (a) is shown by Mn. in perfect records interspersed with low scores, due to kinaesthetic imagery disappearing while recording; (b) is shown by Rt. who extends the first group of letters from five or six to seven or eight, and Al. who extends the first group of a series from two or three, to three or four and the last group from two to three; and (c) is shown by Mn., Rt., and Sl., in fewer substitutions and misplacings.

Change of method was advantageous to those reagents who made it: Group 2. Wf. improved his score 11%; Group 3. Ds. 61.2%; Le. 39%; Group 4. Ms. 48%.

(10) *Memory of Numerals*

Memory for digits serially presented, usually in auditory form, has been used as a mental test (Jacobs,[1] Bolton,[1a] Münsterberg,[2] Toulouse,[3] Cattell and Farrand,[4] Ebbinghaus,[5] Wissler,[6] Binet,[7] Pohlmann,[8] Krueger and Spearman,[9]

Sharp[10]); sometimes for the purpose of measuring attention (Bolton,[1a] Binet[7]). Digits were preferred to non-sense syllables by Cattell and Farrand.[4] Our test (see p. 79) is similar to Whipple's Test 38 A. (2), Variation (1);[11] series of 10 printed digits were presented visually with the Jastrow tachistoscope.

Methods varied in their general characteristics as follows:

(a) Repetition 1) of single numerals (Tn., Le., Sl., Ds., Cr.)
2) in rhythms (Le., Ms., Rt., Tn., He., Al.)
3) Naming once.
4) Naming over and over.
3) and 4) are both combined with both 1) and 2).

(b) Grouping (4-place Mn.; 3-place Wf.; 5-p Ds., Cr.).[102]
(c) Apperceptive grouping or relating (Ly., He., Wf.).[103]
(d) Associating with numbers recorded in a preceding series (Ms.).

Recall was through various imagery and was usually complex: Auditory (Mn.), auditory-visual (Ly.), kinaesthetic-visual (Rt., Le., Sl., He.), kinaesthetic-auditory-visual (Cr.), and through associations (Ly., Wf.). Sometimes the disparate imagery supported each other on the same numerals recalled;

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[1] Jacobs: Experiments on "prehension." Mind. 1887. [o.s.] 12:75ff.
[1a] Bolton: Growth of memory in school children. Am. Jr. Psych. 1891-2. 4:362ff.
[2] Münsterberg: Beiträge zur experimentellen Psychologie. Heft 4. 1892. 121ff.
[3] Toulouse: Enquête medico-psychologique sur les rapports de la supériorité intellectuelle avec la névropathie. (Zola). 1896. 222.
[4] Cattell and Farrand: Physical and mental measurements of the students of Columbia University. Psych. Rev. 1896. 3:644.
[5] Ebbinghaus: Ueber eine neue Methode zur Prüfung geistiger Fähigkeiten und ihre Anwendung bei Schulkindern. Zeits. f. Psych. 1897. 13:410.
[6] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon. 1901. 3: No. 6. p. 9.
[7] Binet: L'Étude expérimentale de l'Intelligence. 1903. Pp. 240ff.
[8] Pohlmann: Experimentelle Beiträge zur Lehre vom Gedächtnis. 1906.
[9] Krueger and Spearman: Die Korrelation zwischen verschiedenen geistigen Leistungsfähigkeiten. Zeits. f. Psych. 1907. 44:50ff.
[10] Sharp: Individual psychology: A study in psychological method. Am. Jr. Psych. 1899. 10:351.
[11] Whipple: Manual of mental and physical tests. 1910. P. 364.

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[102] *Cf.*, Müller: Zeits. f. Psych., Erg. Band 5. S. 211.
[103] *Idem.* S. 215; also Knors: Archiv f. d. ges. Psych., 17:340.

sometimes coöperated in holding their respective numerals independently.

The following reagents used different methods in the final test from those used in the first: He. added to his 2-place method of naming, an apperceptive element by relating the number to 100, and he dropped his visual reproduction of the last numbers in a series for kinaesthetic imagery. Cr. changed from kinaesthetic-auditory, and visual for the last two letters, to a complex grouping involving 2-place and 3-place numbers, as, " "', " "'. Le. changed from a rhythm of four to a mere repetition. Al. changed from a total impression to groups of 4, 6. Ms. changed from a rhythm of five to a single naming with effort to associate the numbers with the figures recorded in the preceding series, which essentially changed the process to memory of associated pairs. Wf., who had used kinaesthetic imagery supported by associations (perceived relationship between the figures in the series, such as products, squares, cubes, etc.), changed to grouping into 3-place numbers. Tn. and Ds. changed respectively from a rhythm of 6, 4, and a grouping into 5-place numbers, to serial repetition from the beginning, after each exposure, which they had just used with the consonants.

Individual differences in processes between the reagents who did not change their methods radically were: Mn. recalled from auditory imagery of 4-place numbers. Rt. used a kinaesthetic rhythm for six digits, and visual imagery for the last four. Sl. named in pairs, 2-place numbers, and recalled the last figure or two visually. Ly. used associations furnished by perceiving relations between the numbers, their sums and differences, retained the numbers expressing the relationships visually, and recalled the numbers themselves from auditory imagery supported by the association-meanings.

Initial capacity ranged from .37 to .92 points, per series, and classifies the reagents into four groups: .8, .6, .5, .4.

Improvement in per cent of increase over initial efficiency, for the reagents who did not radically change their methods, was:

	Regular	1st Control	2d Control
Group 1.	Mn. 17		
	Rt. -7*		
Group 2.	Sl. 30		
Group 3.	Ly. 15		

*This score illustrates the inadequacy of the Spearman "Footrule for scoring the memory test;" (*vid.* Whipple: Tests, p. 367). The loss was caused by four reproduced numerals in correct order being misplaced; omitting this score, the reagent shows a gain of 12%.

These reagents presumably improved somewhat by reason of their training, the results comparing favorably with those of corresponding groups in the preceding test, but since there are no control averages to compare with them, the supposition rests unproven.

Those who changed methods, with one exception gained more: Group 1. Cr. 10%, He.-2%; Tn. 16.7%; Group 2. Wf. 52%, Ms. 33%; Group 3. Ds. 11%; Group 4. Le. 17%, Al. 70%.

(11) *Memory of Visual Signs*

The signs (see p. 79, and Appendix B. Fig. 11, p. 291) were so unfamiliar that, although they were clearly perceived in the one-second exposures, they were not apperceived and therefore were not usually subject to recall. However, some of the signs suggested to the reagents familiar things or conventional characters, and in this way made an impression that could be utilized for recall. This impression did not need to be largely visual, as the test presupposed, but could be converted into any other imagery that would serve as a carrier for the suggested thing, plus a modicum of visual or other imagery which suggested any necessary variation in the drawing. Thus, none of the reagents reproduced more than the last sign from purely visual memory; but gave the symbols names of the things they resembled, as, d, J, 8, 10, omega, phi, dutch cap, etc., and approximated the signs in their reproductions through retention of these names, principally in verbal imagery, and secondary criteria of deviation from the outline of the conventional thing.

The test shows the impossibility of forcing the use of visual imagery by such material and method.[104]

(12) *Memory of Associated Pairs*

Memory for "paired associates" is a variation of Müller and Pilzecker's[1] "Treffermethode," and has been used with vocabulary material (Bourdon,[2] Thorndike[3]). Our method (see p. 79; also Appendix B, Fig. 10, p. 290), differs from the original in the simultaneous presentation of the pairs to be associated. A printed consonant and a printed digit were presented together in series of 10; recall of the digit was required upon a second presentation of its associated consonant.

The process was intended to be memory of contiguous associations, but since this was more difficult or unfamiliar than memory of serial order, the latter was not always inhibited, and introspections are not sufficiently full to be trustworthy in reporting this source of error.

Processes, so far as introspections indicate them, varied greatly: The usual process was to name the letter and digit together so as to get a strong unitary kinaesthetic, auditory, or kinaesthetic-auditory, image of the pair; and when the letter appeared alone it was again named to recall its associate. It is a simple process, and if the reagents had been so instructed they probably could have adhered closely to it without great variation. But variation appears immediately in the 'aufgabe,' and introspections scarcely more than indicate that it occurred.

Mn. said the numeral came as an unfinished syllable of a word.

Mn., Le. and others found that familiar or significant letters held their associations best.

He. and Ms. found visual (G6, C5) and other associations: H2 from chemistry; C3 from alphabetic order, etc.

Rt. and Ly. supplemented kinaesthetic imagery with visual, and found some combinations easier to pronounce.

Mn. and Ly. were caused some distraction by having to inhibit a tendency to notice serial order.

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[1] Müller und Pilzecker: Experimentelle Beiträge zur Lehre vom Gedächtniss. Zeits. f. Psych. Erg. 1900. 1:2.

[2] Bourdon: Recherches sur l'habitude. Année Psych. 1901. 8:327ff.

[3] Thorndike: Memory for paired associates. Psych. Rev. 1908. 15:122ff.

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[104] *Cf.* Kuhlmann: On the analysis of the memory consciousness; a study in the mental imagery and memory of meaningless visual forms. Psych. Rev., 1906, 13:316ff.

He. found that some associates not repeated came up for recording. The attitude of the reagents toward these indefinite associations varied somewhat in the two tests and would be a source of error in the results. This attitude is indicated by the relative number of recorded associations that proved correct:

Per cent, of the numbers recorded, that were correct.

	First	Final
Mn.	39	43
Le.	56	83
Rt.	56	42
Sl.	54	41
Ly.	56	56
He.	91	80
Cr.	30	50
Al.	50	16
Ms.	31	66
Wf.	93	66
Es.	52	94
Pe.	42	46

Results show that there was a general tendency for associates of earlier series to persist and cause errors, especially if they were intensified by significant letters or by mnemonic connections.

The initial capacities ranged from .08 to .42 points and results are so irregular as to make their inspection unprofitable.

(13) *Learning 12-Letter-Rectangles*

Memory for consonants, simultaneously presented in a "letter-square" under conditions of number of letters and time of presentation that preclude a perfect score, has been used for two principal purposes: (1) to study the mental imagery (Binet et Henri,[1] Toulouse,[2] Cohn,[3] Segal,[4]); and (2) to test mental ability (Binet,[5] Sharp,[6] Winch[7]). The test is standardized for the former purpose by Titchener[8]; for the latter by Whipple.[9] It has also been used for the study of the relation of attention to memory (Smith[10]). The letter-square, or, more precisely, the letter-rectangle usually contains 12 letters in three horizontal rows, and is presented from 10 to 20 seconds. Our test (see p. 80) is similar to Whipple's and follows Cohn, Smith, and Segal: 12-consonant-rectangles exposed 10″; reproduction after a free interval of 10″.

[1] Binet et Henri: La psychologie individuelle. Année Psych. 1895. 2:436ff.

[2] Toulouse: Enquête medico-psychologique sur les rapports de la supériorité intellectuelle avec la névropathie. (Zola). 1896. P. 182.

[3] Cohn: Experimentelle Untersuchungen über das Zusammenwirken des akustisch-motorischen und des visuellen Gedächtnisses. Zeits. f. Psych. 1897. 15:162.

[4] Segal: Ueber den Reproductionstypus und das Reproduzieren von Vorstellungen. Archiv f. d. ges. Psych. 1908. 12:133ff.

This is a fairly simple exercise, like most of the other standard "Mental Tests," yet it, too, may evoke quite different processes in the various reagents, and may become several different tasks even to the same individual.

The effect of practice on the processes involved was described some pages back (pp. 94ff.), in the discussion of training results. Here we have to do with fairly initial abilities, except in the final tests of Rt. and Sl., who trained on this work, in which variability shows itself freely.

The reagents attempted the task by:

(a) Reading in vertical columns of 3 letters.
(b) Reading in lines of four letters (the general method).
  1) Rote repetition, over and over, for kinaesthetic-auditory impression.
  2) Fewer repetitions, apperceptive; grouping of letters, rhythm.
  3) Visual impression; intensified or casual.
  4) Associating letters.[105]
    a) by sound, rhyme.
    b) by form (e.g., VWYM, CGQ).
    c) by alphabetic position (BC, KL, XZ).
    d) by signification; favorite form, initials, abbreviations, words, etc. (DV, deo volente; SFTR, San Francisco Teddie Roosevelt, or sifter).

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[5] Binet: Attention et adaptation. Année Psych. 1899. 6:324ff.
[6] Sharp: Individual psychology: A study in psychological method. Am. Jr. Psych. 1899. 10:353.
[7] Winch: Immediate memory in school children. I. Visual. Br. Jr. Psych. 1904. 1:128.
[8] Titchener: Experimental psychology. 1901. Vol. I. Part II. Instructor's Manual. 396ff.
[9] Whipple: Manual of mental and physical tests. 1910. Test 38, B. 368.
[10] Smith: Relation of attention to memory. Mind. 1895. N.S. 4:47ff.

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[105] For advantage of logical connections, *vid.* Balaban: Zeits. f. Psych. 56: 356-377, 379-400. For agreement of these results with others, *vid.* Smith: *op. cit.* p. 57; Cohn: *op. cit.* pp. 178ff.; Segal: *op. cit.* S. 160; and Michotte et Ransy (Contribution a l'étude de la mémoire logique. Études de Psychol. 1912. 1:72-81). Calkins (Psych. Rev. 5:460) found the tendency to combine unrelated concrete words in four-fifths of her 52 reagents; three-tenths of the words, chosen to prevent natural combinations, were forced through imagery into some sort of relation.

To illustrate:

P	H	Q	K
D	S	T	N
L	G	R	F

(a) Continuous repetition of the first line and the first column, on the accompanying 12-letter-rectangle, yielded 15 points (Le.); or of the first two lines, 22 points (Rt.).

(b) Repetition of letters in lines, by pairs, yielded 20 points (Le.).

(c) Repetition of the first two lines; visual image of the last line on the forehead, gave 24 points (Sl.).

(d) Wholly representative (Phone quick, long distance, lograft) gave 36 points, a perfect score (Cr.).

Clearly those four methods involve different kinds of work, besides yielding different scores.

Reproduction was usually in combined imagery; the more common being, kinaesthetic-auditory, but often also auditory, visual, and representative (associations), upon the same letters. Then different letters were sometimes assigned to the different forms of imagery so that their coöperation yielded more letters than could be reprodued by combining on the same letters. Sometimes only the imagery representative of the letters was prominent; *i.e.*, but little imagery of the letters, when associations for them were used.

Some of the reagents made radical changes in their methods in the final tests: Mn., Cr., Ms., and Bt., changed to much greater use of associations; Le. from more rapid repetition, over and over, to a single apperceptive repetition and the use of associations.

Other reagents retained their old methods:

Rt., who trained on this work, repeated the first six letters for reproduction from kinaesthetic imagery; the next two letters were assigned to a visual association, or were reinforced for a visual recall, and the last line casually observed for visual recall to be recorded first while retaining the more vivid imagery to be recorded later.

Sl., who also trained on this work, repeated the first two lines for kinaesthetic recall, and fixed the last line by associations, with meaning, or by visual imagery, which was very unstable.

He., Ly., and Wf. made forming associations a method.

Al. sought to get a kinaesthetic-auditory impression of the whole card.

Initial efficiency ranged from 15.5 to 27.3 points, classifying the reagents into four groups: 27, 22, 18, 16.

Improvement upon initial efficiency, for the reagents whose methods remained practically the same, was:

	Regular	1st Control	2d Control
Group 1.	He. 7		
Group 2.	Ly. 26	Wf. 8	
Group 3.	Sl. 45 Rt. 44 Al. 4		
Group 4.			Ed. 12.3

Ly.'s is the only score that invites speculation. Her method was to form associations, and her improvement is due to doubling her facility in forming them; this differs greatly from improvement in vivifying impression and heightening the power of recall of imagery, which contributed to the improvement of Rt. and Sl., and seems in no way to depend upon her training in simple reaction. In her method variability is greater than might at first be supposed: In the final test, although the material presented was the same as that of the first test, (a) different letters were chosen for the associations, and (b) when the same letters were chosen the associations were sometimes different (DZ dizzy, Diaz; WSH wash, Washington). Facility in forming associations varied greatly, irrespective of material, even within the same test; *e.g.*, in the first test, Ly. began with forming associations as a method, and by the fourth experiment had made a perfect score by holding all the letters in associations, but when the 7th card, used in the above illustration, was exposed, she could find no associations for the letters and was reduced to repeating them in pairs, making a score of 10 points, (half her average). In her first test 48% of her recorded letters were held in associations, in her final, 90% were so held.

Change in method was advantageous (improvements being: Group 2. Cr. 26%; Group 3. Mn. 64%, Bt. 27%; Group 4. Ms. 48%, Le. 14%), sometimes more than any other circumstance; as is well illustrated in the case of Ms., a control reagent, who, although her initial ability was but a little below theirs,

showed greater improvement than was made by either of the two reagents who trained on this work 18 days.

An interesting effect of the training on this work is found in the results of Rt. and Sl., in comparison with the results of others, obtained on additional experiments in this test, three in which numerals were exposed, and one in which commercial signs were exposed: These reagents carried over their method, as recorded above, to the numerals, changing from 4-place and 2-place grouping, respectively, and made 83% and 70% improvement (while the other reagents ranged from loss to 55% improvement), and this improvement is greater than was made with the consonants upon which they trained. To the commercial signs, the method was absolutely unfitted, and they alone lost in the scores of the final test (Rt. 7%, Sl. 17%), Sl., whose method was the more mechanical, losing the most.[106]

The chief factors of improvement in this test were:

(a) More adequate method.

(b) Better coördination of the kinaesthetic, auditory, and visual modes of imagery, and assigning them to different material rather than permitting them to merely support each other in making vivid a smaller number of letters.

(c) Better impression and recall through each kind of imagery.

(d) More use of associations.

(e) Associations more apperceptive.

(14.) *Same. With Distraction*

Distraction in learning consonants visually presented in letter-rectangles has usually been applied to the period of perception (Smith,[1] Cohn,[2] Segal[3]) and has consisted in counting, adding, or intoning a vowel sound; occasionally the distraction has been applied to the interval between perception and reproduction (Bingham,[4] Finzi[5]). In our test (see p. 80) the reagent was required to add digits pronounced by the experimenter during the interval between perception and reproduction, and to write down the sum before he began recording his letters.

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[1] Smith: *op. cit.*, 47ff.
[2] Cohn: *op. cit.*, 162.
[3] Segal: *op. cit.*, 133.
[4] Bingham: Memory, II. Psych. Rev., 1894, 1:453ff.
[5] Finzi: Zur Untersuchung der Auffassungsfähigkeit und Merkfähigkeit. Psych. Arbeiten, 1899-1901, 3:295.

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[106] *Cf.* Sleight, *op. cit.*, pp. 440, *et seq.*

Interpolation of processes, as usual, again increases variability in processes and results.

In the preceding test attention could be given, during the 10-second interval between impression and recording, to the retention and fixing of the letters; in this, a variable division of the attention takes place between retention and adding, resulting in a further important source of variation beyond those of the preceding test.

(a) The adding may be carried on either in visual imagery, or auditory imagery, partial sums being kinaesthetically imaged or repeated, while the attention shifts quickly[107] to the verbal or other imagery from which the recall of the letters is sought to be made.

(b) The whole attention may be given to the adding in the interval while the numbers are pronounced.

(c) Or, attention may be given to further fixing the imagery of the letters for surer recall, and turn with leisure and confidence to the auditory images of the numbers after they have all been pronounced.

The first method is apt to lead to incorrect sums and to great decrease in the score; the second to correct sums, but to decrease in the score; the third to correct sums, if auditory imagery is fair, and to a good score.

Variability is further increased by the varying degrees of conflict between the part-processes. Difficulty in adding, using the first method above, dispersed clear imagery, because of confusion of mind it occasioned (Le.). Both kinaesthetic and visual imagery were interfered with, when the second method was used (Rt.). Associations escaped when they were merely verbal, because of the conflict with kinaesthetic impressions in pronouncing the partial sums (Ly. He.).

Since recall is surer from associations than from imagery of the letters,[108] almost all reagents resorted to them, but with

[107] Smith (Mind. N.S. 4:66) found that the attention of his reagents, who were set to learning the letters while adding, oscillated between the two tasks.

[108] In the preceding experiment, when letters had been fixed in an association, no further attention was given to them, the interval being filled with

varying facility. Not only the readiness to form associations was variable, but selection of such kinds of associations as involve more apperception was variable, and, consequently, retention of associations was variable.

The whole association may be lost; or by a slight cue may yield its quota to the score. The following will illustrate how near a 0 score is to a score of 100%, when associations are used: A reagent gave full attention to adding during the interval, recorded a correct sum, and found that he could not recall a trace of his associations or even a letter; after a moment, weak kinaesthetic imagery brought back the association of the first two letters; then in recording these, associative connections grew stronger and the associations all returned (led by meaning rather than by verbal imagery), and a perfect score was produced (Cr.).

An association may be recalled, however, and be either untrustworthy or useless, because of the absence of further imagery relating the letters definitely to it. The influence of the imagery is seen in the record of VNWY from the associated word "Vanity"; **Van**(it)**y**; the substitution of "W" for "it" was held in visual imagery (Cr.). The adding was often fatal to this imagery as may be seen from the failure of "North Buckham" to produce NRT BKYM by producing NTH, thus yielding the lowest score of the series (Cr.).

None of the reagents were constant in their methods, and initial ability ranged from 8.3 points to 19.5. Distraction ranged from 15% to 60%.

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effort to retain by repeating letters held in less sure imagery. At the beginning of the first test, here, the reagent said: "I rested my attention on the last column more than on any other, but the second seemed to form a word; I retained the latter and could not remember the former." (Mn.). This conforms with the findings of Balaban (*op. cit.*) that associative learning was eight times more effective than mechanical memorization, and of Arnold (The initial tendency in ideal revival. Am. Jr. Psych., 1907, 18:251) that recall is insured by a more closely organized disposition, a better developed meaning, a more complete organic whole.

(15) *Word-Completion*

This test (see p. 80f.) is an application of Ebbinghaus'[1] "Completion Test" to words, and differs from Whipple's[2] "Word-building" test in greatly limiting the possible combinations. It involves equivocal reproduction or controlled association, and was designed to measure a narrow type of inventive or imaginative power.

Some of the reagents completed the list in less than 100 seconds; others left it unfinished in 300. The process differed greatly, especially with respect to the 'Aufgabe.' All reagents sounded the consonants phonetically, interpolating between them indefinite vowel sounds, until a word was called up by the kinaesthetic-auditory cue. Upon a hitch in getting a word, some of the reagents (Le., Rt., Cr., Ms., Wf.) started systematically sounding definitely the various vowels, taking them in order, between the first pair of consonants. Only once did the visual form suggest a word (Rt.).

Although instructions were clearly given to add letters anywhere to complete a word, only twice did an added letter precede the first consonant (Ly., Ms.), and occasionally the reagents otherwise limited their task, *e.g.,* Le. and Ms., after their experience in the first test, limited additions in the final test to the two spaces between consonants, and failed to complete the ten words within the 5-minute time-limit; He., in his first test, limited himself in the first few words to the space between the first pair of consonants, and after leaving an incomplete word and properly assigning himself to other spaces in completing following words, he returned to it, again limiting himself as before.

Since the difficulty of the task depends upon the 'Aufgabe,' which the reagent holds in his mind, it is obvious that quantitative results, without adequate introspection, are without value. Even with adequate introspection, there is no way to equate results when the processes are greatly different.

The test is of value in showing how, under precisely the same

[1] Ebbinghaus: Ueber eine neue Methode zur Prüfung geistiger Fähigkeiten und ihre Anwendung bei Schulkindern. Zeits. f. Psych., 1897, 13:401ff.; also Whipple's Test 48, p. 445ff.

[2] Whipple: Manual of mental and physical tests, 1910, Test 27, pp. 441ff.

instructions and external conditions, different reagents vary widely (a) in the task to be performed, and (b) in the processes they use to carry out a similar task.

(16) *Trains of Ideas*

The mental processes involved in free reproduction or uncontrolled association made early contribution to experimental psychology. They furnished Galton,[1] as he walked along Pall Mall and noted the ideas that came into his mind as he scrutinized successive objects that caught his eyes, material which he learned to subject to measurement. They are, of course, employed for mental diagnosis in the famous "word-association" test; and they have been employed in unbroken series of from 10 to 100 words[2] for the study of association (Cattell and Bryant[3]), of effect of immediate environment upon association (Flournoy[4]), of community of ideas of men and women (Jastrow, [5] [7] Nevers,[6] Calkins,[8] Tanner,[9]), of individual differences in mental processes (Secor,[10] Binet[11]); but they have also been used in unbroken series for determining rate of mental activity (Wissler,[12] Thompson,[13] Brown[14]). In our test (see p. 81) 2-minute series were written after the stimulus words: "horse," "potato," "flute."

Since most of the individual scores run up to about the maximum speed in writing, it may be presumed that in this test, when the ideas are recorded by the reagent, reproduction is seriously limited by recording. Even were the phrases and

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[1] Galton: Psychometric experiments. Brain. 1879-1800. 2:151.

[2] *Vid.* Whipple: Manual of mental and physical tests. 1910. Test 33, pp. 313ff.

[3] Cattell and Bryant: Mental association investigated by experiment. Mind. 1889. 14:230ff.

[4] Flournoy: De l'action du milieu sur l'idéation. Année Psych. 1894. 1:180ff.

[5] Jastrow: A study in mental statistics. New Review. 1891. 5:559ff.

[6] Nevers: Dr. Jastrow on community of ideas of men and women. Psych. Rev. 1895. 2:363ff.

[7] Jastrow: Community of ideas of men and women. Psych. Rev. 1896. 3:68ff.

[8] Calkins: Community of ideas of men and women. Psych. Rev. 1896. 3:426ff.

[9] Tanner: The community of ideas of men and women. Psych. Rev. 1896. 3:548ff.

[10] Secor: Visual reading: A study in mental imagery. Am. Jr. Psych. 1899-1900. 11:225ff.

[11] Binet: L'Étude expérimentale de l'intelligence. 1903. P. 309.

[12] Wissler: Correlation of mental and physical tests. Psych. Rev. Mon. 1901. 3: No. 6, p. 8.

[13] Thompson: Psychological norms in men and women. Univ. Chicago Contrib. to Phil. 1903. Pp. 100ff.

[14] Brown: Some experimental results in correlation of mental abilities. Br. Jr. Psych. 1910. 3:306.

words spoken, the process would be similarly limited in speed. Scores, therefore, do not so much show rapidity of reproduction as rapidity of expression and regularity of reproduction. And since the whole field of the reagent's experience is available for reproduction, with all the grades of liability for recall, variation in regularity is inevitable; nor does it seem that variable attention rather than direction of 'leads' into various fields of experience is the greater cause of variation.

Initial efficiency ranged from 55 to 100 ideas for the six minutes.

Qualitatively, some interesting facts were presented:

(a) The 'Aufgabe' was not the same for all reagents, although instructions and external conditions of the experiment were uniform. The usual method was to begin with the idea suggested by the stimulus-word and follow the course suggested by the last word until new 'leads' would develop from some prominent member of the last series, or 'story,' thus introducing a new 'story,' etc. But Sl. bound himself to record only ideas related directly to the stimulus-word, and gave second place to the suggestion of recorded ideas; and Wf. followed an intermediate course approaching closely Sl.'s method.

(b) Most of the reagents find that of the flood of memories and images only a few, usually the most prominent, can be recorded.

(c) The 'stories' from which the constellations of ideas are chosen for recording are related to various periods of the reagent's experience and tend to fall upon the same periods of experience, for all stimulus-words given in one sitting, but upon different periods for the same stimulus-word given upon different days. This merely indicates 1) the organization of experience, in cross-section; and 2) the flux of experience, in longitudinal-section. Ms. in her first test drew mainly upon experience of her childhood; in her final test, upon those of recent years and days.

(d) The remote and recent experiences are sometimes drawn upon in the same minute, due to the prominence of identical factors in their memories; emotional or cognitive.

(e) Anxiety about one's work, or great interest in an event, leads all trains of ideas to that center of interest, even when approaches are repeatedly inhibited (Cr., Le.). This shows how efficient the selective influences are, in the control of the central elements of consciousness. Monomania would seem to be but an exaggeration of this natural process. In this case the control seems to be given over to the emotional set of consciousness.[109]

(17) *Extensive Threshold of Visual Attention. Free*

The number of letters that can be apprehended in a momentary exposure of a rectangle containing from 6 to 12 letters has been thought to constitute a measure of the "extensive threshold of attention" (Wundt[1]) or the number of elements that can be simultaneously grasped by consciousness. The time of presentation is usually about 0.1 seconds, less than the eye-reaction time, in order to limit apprehension to a single fixation of vision; but owing to the persistence of the after-image for about 0.25 seconds (Schumann,[2] Hylan,[3] Messmer[3a]) and to the visual memory after-image that may appear a few seconds later (Schumann[2]), the attention may fluctuate successively over the elements so held, thus augmenting unduly the measure of the threshold of attention and relating it to the 'memory-span' for successively presented letters. Wundt[1] warns the reagent to avoid this error through introspectively distinguishing between the simultaneous and the successive activities. The test has been used to measure visual perception and attention (Griffing[4]) or the range of visual attention (Whipple[5]). In our test 12-consonant-rectangles were presented for about 0.1 sec. (85 sigma); reproduction was required after a free interval of 5 seconds (see p. 81).

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[1] Wundt: Grundriss der Psychologie. 10te Auf. 1911. Sec. 15, Par. 6 (pp. 254ff.); also Grundzüge der Physiologischen Psychologie. 5te Auf. 1902. III:351ff.

[2] Schumann: Die Erkennung von Buchstaben und Worten bei momentaren Beleuchtung. Bericht u.d. I. Kongress f. Exp. Psych. 1904. 34-40; *also* Psychologie des Lesens. Bericht u.d. II. Kongress f. Exp. Psych. 1906. S. 174.

[3] Hylan: The distribution of the attention. Psych. Rev. 1903. 10:373, 498.

[3a] Messmer: Zur Psychologie des Lesens bei Kindern und Erwachsenen. Archiv f. d. ges. Psych. 1903-4, Bd. 2, S. 206.

[4] Griffing: On the development of visual perception and attention. Am. Jr. Psych. 1895. 7:277ff.

[5] Whipple: Effect of practice upon range of visual attention and of visual apprehension. Jr. Ed. Psych. 1910. 1:249ff.

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[109] This test furnishes a good diagnosis of the reagent's experience at the time it is taken. Repeated tests would make it quite possible to characterize the reagent's mental life. A person could not in a briefer or more efficient way keep a diary of his real interests than by this two-minute test, accompanied by a commentary.

Analysis of processes involved in the work of this test was made under the head of Training Results, some pages back (pp. 82ff.); only a general indication of the fact of variability of processes, therefore, need be made here.

(a) The field of the attention may vary from the whole card to a line or to a few spaces. In the first case, vague imagery makes up the bulk of the material dealt with; in the second, both clear and vague are entertained; in the third, only clear imagery.

(b) The type of imagery may determine the process: If the visual impression is immediately converted into kinaesthetic or kinaesthetic-auditory imagery, reproduction is largely limited to letters clearly seen; if the visual impression is held for a while, before being converted, more dimly seen letters become fixed.

(c) If the attitude toward vague imagery is encouraging, some unrecognizable imagery 'matures' into letters, the record of which the score often justifies.

(d) If, in recall, disparate imagery supplements itself on separate letters, more letters are recorded.

(e) Some distraction seemed peculiar to the test: Readiness of the naming process was not at times satisfactory because of low reproductivity of the letter-names; to some reagents some combinations of letters were retarding because of the non-euphonious pronunciation of their names; to some, special letters (significant or disagreeable) retarded the process; several times exposures were completely missed by winking.

Introspections show that the process varied with each reagent in each test, and sometimes considerably between tests.

There was a general effort to convert the visual impression or visual imagery into kinaesthetic imagery or impression (incipient pronunciation); this conversion reduces reproduction to a 'rote' process, which doubtless is the line of least resistance in memorizing. Introspection says: "First the imagery is very intense, visual, which I convert into kinaesthetic (verbal); then I repeat rapidly, almost as one word, and this is accompanied by weak visual imagery. Then I seem to feel sure of the letters—they seem to lie on my tongue and are less full of meaning than at first" (Rt.). "After repeating letters I felt confident that I had them; they would not fly away" (Wf.).

In practice, the moment of this conversion was adjusted by the necessity of fixing many distinct impressions before they got away, and the necessity of permitting them to mature more clearly in order to be either cognized or held in visual imagery in sufficiently stable form to remain while fixing others by naming. The shifting of this moment was necessitated by the varying grades of clearness of the imagery, and inexpert shifting was fatal to the score. Better coördination of processes here resulted through practice, and variation in methods as indicated above must be credited with considerable variation between individual reagents, resultant upon this particular practice effect.

Initial capacities varied in average scores from 4.1 to 9.1 points (3 points to a correctly placed letter), and divide the reagents into four groups: 9, 8, 6, 5.

Improvement in per cent upon initial capacity, for the reagents who retained in their final tests their old methods, was:

	Regular		1st Control		2d Control	
Group 1.	He.	12				
Group 2.	Le.	58	Wf.	21	Ty.	4
	Rt.	10				
Group 3.	Al.	45				
	Cr.	42				
Group 4.	Sl.	25				
	Ly.	14				

Al. differed from the other reagents in attending consistently to the whole card.

Three reagents made radical changes in their processes in the final test: Mn., who trained 18 days on this work; and Ms. a control reagent, changed from attending to the whole card to attending to limited parts of it, usually the first line. Dn. changed from intentionally varied methods in the first test, involving attending to the whole card, limiting the field in various ways, and closing one eye and then the other to see if a clearer impression could not be obtained, to a regular method of restricting the field and of binocular vision. These changes were advantageous: Group 4. Mn. 147%, Ms. 47%; Group 5. Dn. 39%.

That great difference in the score results from variation in the extent of the field attended to, is illustrated by individual scores made by Ms. in her first test. In the first six experiments, with attention upon the whole card, she made no score above 4 points; in the last four experiments, with the field restricted to the upper right-hand corner, she made no score below 8 points. Mn.'s great gain is based upon those six experiments, for the averages of the scores of the last four experiments in her first test is higher than the average of either the last four or all of the experiments of her final test.

The results of this test offer several anomalies which indicate the futility of merely quantitative treatment of work of this kind. Ms., a control reagent, shows greater gain than does Al., who trained on this work for 8 days; besides (a) the difference in capacity, indicative of difference in kind of work, (b) the gain is exaggerated by the per cent being reckoned upon lower initial capacity. Wf., a control reagent, shows a greater per cent of gain than He.; although their initial capacities are not so unlike, this excess of gain is illusory, since in absolute gain He. excells, and from He.'s greater initial capacity, it is conceivable, improvement is more difficult to make.

Cr. and possibly He. are the only reagents who appear to have brought to the test any advantage from their training; both improved more than the other reagents who did not train in this work, in regular performance indicative of more constant conditions of attention.

(18) *Same. With Distraction*

Adding four digits during an interval of 5 seconds between perception and recording is a doubtful distraction, ranging from 0 to 59%. It was but negligible for Mn. in both tests; for Sl., Ly., and Dn. in the first test, and for He. and Al. in the final test; and it varied between the two tests considerably for all the reagents except Mn., Cr., and Ty.

The chief cause of variation in the scores (initial capacity ranged from 3.2 to 6.9 points, and final capacity from 2.8 to 11.4 points) was the conflict between the visual or kinaesthetic-

auditory imagery in which the letters were being held and the kinaesthetic imagery of the partial sums in adding. Where distraction was overcome, the usual method was to quickly name the letters and thus fix them in kinaesthetic imagery, and add the numerals at leisure from auditory images after they had all been pronounced.

(19) *Tapping*

Tapping as rapidly as possible during an interval of from 5 seconds to 2 minutes, with a pencil, stilus, or telegraph key, has served as a test for voluntary motor ability and, with the longer intervals, for fatigue (Bryan,[1] Dresslar,[2] Gilbert,[3] Moore,[4] Binet et Vaschide,[5] Kirkpatrick,[6] Bagley,[7] Bolton,[8] Kelly,[9] Thompson,[10] Burt,[11] Wells[12]), and has been standardized by Wells[13] and Whipple.[14] Our test follows Wells: 5 series of 30″, with 2.5′ rests. (*Vid.* p. 81f.).

Maximum rate of voluntary activity as expressed in tapping on a Morse key (adjusted as preferred by telegraph operators—1 mm. amplitude, 50-gram tension) seems a very simple process. But our results show it to be variable and to depend upon other important factors besides attention and fatigue.

Results gave the "Total Efficiency" (average number of taps

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[1] Bryan: On the development of voluntary motor ability. Am. Jr. Psych. 1892. 5:123ff.

[2] Dresslar: Some influences which affect rapidity of voluntary movements. Am. Jr. Psych. 1892. 4:514ff.

[3] Gilbert: Researches on the mental and physical development of school-children. Studies from Yale Psych. Lab. 1894. 2:48.

[4] Moore: Studies of fatigue. Studies from Yale Psych. Lab. 1895. 3:92ff.

[5] Binet et Vaschide: Expériences de vitesse chez les jeunes gens. Année Psych. 1897. 4:200ff; also Épreuves de vitesse chez les jeunes garçons. *ibid.* 64ff.

[6] Kirkpatrick: Individual tests of school children. Psych. Rev. 1900. 7:274ff.

[7] Bagley: On the correlation of mental and motor ability in school children. Am. Jr. Psych. 1900-1. 12:195ff.

[8] Bolton: Relation of motor power to intelligence. Am. Jr. Psych. 1903. 14:354.

[9] Kelly: Psychophysical tests of normal and abnormal children; a comparative study. Psych. Rev. 1903. 10:345ff.

[10] Thompson: Psychological norms in men and women. Univ. Chicago Contrib. to Phil. 1903. 4: No. 1. 12ff.

[11] Burt: Experimental tests of general intelligence. Br. Jr. Psych. 1909. 3.132.

[12] Wells: A neglected measure of fatigue. Am. Jr. Psych. 1908. 19:345ff.

[13] Wells: Normal performance in the tapping test. *ibid.* 347-483.

[14] Whipple: Manual of mental and physical tests. 1910. Test 10, pp. 100ff.

per series of 30 seconds), and the "Fatigue Index" (found by dividing the average of the last five intervals of 5 seconds each, of the first series, by the number of taps in the first interval of 5 seconds).

The manner of tapping varied between the different reagents, with respect to the parts of the arm, forearm, wrist, hand, and fingers, put in vibration, with respect to the amplitude of vibration, the manner of grasping the key, the amount of innervation and bodily tension, determination to resist fatigue, and accompanying psychial processes, such as counting the taps in groups. And it varied, in a less degree, in an individual reagent's work.

"Total Efficiency" ranged from 176.8 to 245.8, in the first test, and reagents fall into five groups: 246, 218, 205, 198, 180.

Change in per cent of initial capacity, was as follows:

	Regular	1st Control	2d Control
Group 1.	Rt. -1.5		
Group 2.	He. 5.0		
Group 3.	Sl. 3.2	Ms. -1.3	
	Cr. 3.2		
	Le. -0.2		
	Ly. -2.6		
	Mn. -3.3		
Group 4.		Wf. -1.2	
Group 5.			Me. 0.6
			Wx. 1.2

The changes in the table may indicate changes in fatigue, since objective fatigue is said to increase the time,[110] and the test is recommended as a measure of fatigue;[111] they may indicate changes in the capacity of attention which opposes fatigue; or they may be due to both these causes as modified by others.

That the last conjecture is sometimes true is shown by the results of Rt., Le., and Sl. Rt.'s practice curves of the two tests are precisely the converse of each other; his first curve shows great practice-effect in the second series, reaching a maximum in the third series; his final curve begins with phenomenal speed (267), loses greatly in the second series,

[110] Moore: Yale Studies, 3:95.

[111] Wells: Am. Jr. Psych., 19:344.

reaching minimum in the third series. Le.'s curves are similar but show less practice-effect and loss. Sl.'s final 'fatigue curve' is inverted, differing from all others in showing marked practice-effect up to the fourth interval. Unfortunately, introspections are not sufficiently full to indicate the causes of these variations.

Usually the two practice curves of a reagent are similar: Both show practice-effect in the cases of five reagents (Mn., Sl., Cr., Ms., Wx.); no practice-effect in the case of four reagents (Le., Ly., He., Wf.); and loss in the case of one reagent (Me.).

Susceptibility to fatigue, as is inversely indicated by the "Fatigue Index" (see p. 82), ranged from 87 to 97, placing the reagents into three groups: 95, 90, 85. Complete resistance to fatigue would be 100.

Per cent of change in resistance to fatigue was:

	Regular	1st Control	2d Control
Group 1.	Sl. 18.5	Ms. -5.1	Wx. -1.9
	Le. -9.5	Wf. -11.7	
Group 2.	Ly. 5.6		Me. -1.0
	Cr. 1.1		
	He. -4.4		
	Rt. -5.4		
Group 3.	Mn. -3.5		

The agreement between the two tables showing the "state" of fatigue and the "susceptibility" to fatigue in the cases of Mn., Le., Rt., Sl., Cr., Ms., and Wf. indicates a reliability for the test as a measure of fatigue which is supported, in part at least, by the fact that the final tests were taken at the end of the school-year when most of the reagents could be expected to be working under greater fatigue than when the first tests were taken.

But there are disturbing influences: He. gained 5% in "Total Efficiency" and lost 4.4% in resistance to fatigue; Ly. lost 2.6% in "Total Efficiency" and gained 5.6% in resistance to fatigue; Sl. gains in both, but made in his final test the remarkable "Fatigue Index" of 115, which is supported by his remarkable 'fatigue curve' drawn from the averages of the respective intervals in all series of the final test, which shows a marked practice-effect.

No relation between the results of this test and the training or improvement in attention is evident.

f. Extent of Variability

In the preceding analyses of processes it was shown (a) that in almost every test individual reagents differed from each other, often greatly, in the way in which they performed the work of the test;[112] and (b) that it is the rule for the individual

[112] That individual variation in kind of mental work performed, when reagents set themselves to the same objective task, is not peculiar to the material or the method of our tests, may be seen by inspecting any report of investigation in which the mental processes of the different reagents are subjected to analysis. The contributions to individual psychology and the studies of "imagery type," as has already been noted (foot-note to p. 69), reveal this qualitative variability in every class of mental activity. To select a few typical references for further explication, it is shown specifically in discrimination of clangs (Whipple: An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych. 1901. 12:425-433, 448-452); in memory for sounds of familiar things, presented by a graphophone (Kuhlmann: On the analysis of auditory memory consciousness. Am. Jr. Psych. 1909. 20:194ff), in memory for meaningless visual forms (Kuhlmann: On the analysis of the memory consciousness. Psych. Rev. 1906. 13:316ff), in memory for nonsense-syllables (Müller und Schumann: Experimentelle Beiträge zur Untersuchung des Gedächtnisses. Zeits. f. Psych. 1894. 6:303-5; Pentschew: Untersuchungen zur Ökonomie und Technik des Lernens. Archiv f. d. ges. Psych. 1903. 1:417ff; Ebert und Meumann: Ueber einige Grundfragen der Psychologie der Uebungsphänomene im Bereiche des Gedächtnisses. Archiv f. d. ges. Psych. 1904. 4:1ff; von Sybel: Ueber das Zusammenwirken verschiedener Sinnesgebiete bei Gedächtnisleistungen. Zeits. f. Psych. 1909. 53:327ff), in memory for various material (Bingham: Memory. Psych. Rev. 1894 1:461ff; Whitehead: A study in visual and aural processes. Psych. Rev. 1896. 3:258ff; Gamble: Study in memorizing various materials by the reconstruction method. Psych. Rev. Mon. 1909. No. 43); in word-association (Galton: Psychometric experiments. Brain. 1879-80. 2:158; Calkins: Short studies in memory and in association. Psych. Rev. 1898. 5:460; Mayer und Orth: Zur qualitativen Untersuchung der Association. Zeits. f. Psych. 1901. 26: 1-13; Wreschner: Die reproduktion and Assoziation von Vorstellungen. Zeits. f. Psych. Erg. Bd. 3. 1907, S. 86ff; Koffka: Ueber Vorstellungen. 1911); in imagery of things (Philippe: Un recensement d'images mentales. Rev. Philos. 1897. 44:510; Lay: Mental imagery experimentally and subjectively considered. Psych. Rev. Mon. 1898. No. 7; Slaughter: A preliminary study of mental images. Am. Jr. Psych. 1902. 13:526ff); in spelling (Abbott: On the analysis of the memory consciousness in orthography. Psych. Rev. Mon. 1909. No.

reagent to vary his processes while at work on a test and often to radically change, in the final test, the methods of work employed in the first.[113] What the variations in processes were has been shown in some detail.

Some indication of the extent of *radical* change in method may be indicated by the following table which lists the cases of such change when it occurred between the first and final tests:

Tests	1	2	3	4	5	8	9	10	13	17	Total
No. of reagents	11	12	12	12	11	10	12	12	12	12	116
No. Changed	6	5	4	0	2	6	4	8	5	3	43

The table shows that *in the ten tests in which the results were the more regular, of 116 difference-scores 43 (35%) were affected by change in methods between the first and final tests.* The changes are distributed over the reagents as follows: Regular—Mn. 5, Le. 5, Rt. 1, Sl. 2, Ly. 3, He. 3, Cr. 4, Al. 1; 1st Control—Ms. 8, Wf. 4; 2d Control reagents—3, and 4; which indicates that some reagents are more prone than others to radically change their methods of work.

Introspections for some of the tests (No.'s 6, 7, 19) were not sufficiently full in detail to indicate what the changes were, although large variability among the scores of the series of which the tests were composed indicated that they occurred;

44:127ff.). For especially good analyses the reader is referred to Binet (L'Étude Expérimentale de l'intelligence. 1903. Pp. 282, 246, 306-7), Segal Ueber den Reproductions Typus und das Reproduzieren von Vorstellungen. Archiv f.d. ges. Psych. 1908. 12:175ff), and particularly Müller (Zur Analyse der Gedächtnistätigkeit u.d. Vorstellungsverlaufes. Zeits. f. Psych. Erg. Bd. 5, 1911; 8, 1913). The evidence in these references is based almost wholly upon analysis of adult introspections; but it seems highly probable that functional variability is also extensive among children. Binet (*op. cit.*) found this true of his two daughters, and Winch (The faculty doctrine, correlation, and educational theory. Jr. of Phil. Psych. and Sci. Methods. 1911. 8:377) infers it from the fact that the coëfficient of correlation was low for the early series of learning while it was high for the late series, a fact which when found by Hollingworth (Individual differences before, during and after practice. Psych. Rev., 1914, 21:8) with naïve adult reagents, was used to show "that we are not, in early trials, measuring the same thing with all performers."

[113] Change in processes during practice in discussed on pp. 176ff.

and the results were so extremely irregular in some of the other tests (No.'s 11, 12, 14, 15, 16, 18) that any statistical treatment of them seemed useless.

The extent of variability between reagents may be shown by the extent of the range of initial capacity for each test. If this is reckoned in per cent of the lowest average (the highest capacity for a time-unit; the lowest for a work-unit), we get the following table:

1.	60	5.	86	10.	149	16.	82
*	135	6.	85	12.	425	17.	122
2.	150	7.	70	13.	76	18.	115
3.	204	8.	133	14.	135	19.	39
4.	33	9.	133	15.	452	**	11

*Relative variation of reaction time.
**Fatigue Index.

In Test 1 the range of initial capacity in reaction time was 60% of the highest capacity; in relative variability 135%. In Test 8 the range, in memory of sounds, was 133% of the lowest capacity. (Uncertainty in scoring ruled out the results of Test 11).

The range in initial capacities is usually large. In only three cases is it below 50% of the lowest average; in six cases it is between 50% and 100%; in eight cases between 100% and 200%; in one case 204% and in two cases over 400%. Thus, in over half of the tests the highest initial capacity is more than double the lowest.[114]

[114] Our tests are not peculiar in showing frequent wide ranges in initial capacity. On p. 67 we had occasion to refer to Sleight's (*op. cit.* 410-411) test on "points"; the range in initial capacities for the three schools is shown by Table I to be 27-93, 32-129, 23-132, respectively. Binet's (L'Étude expérimentale de l'intelligence. 236ff) two daughters upon the test of marking out the letters *a, e, d, r, s,* from French text made initial scores of 23.1 and 53.4 respectively; and his six dull and five bright boys upon the same test (Attention et Adaptation. 364ff) ranged from 61-165 and 68-138 respectively. Ebert und Meumann's (*op. cit.* 15, 47ff) six reagents ranged in memory span for numbers 5-9, in learning nonsense-syllables 13-41 presentations, note-form symbols 25-60, sickle-form symbols 33-75. Thorndike and Woodworth's (*op. cit.* 253ff, 385, 556) reagents ranged in average error in estimating areas, 7.7-24.2, 10.5-28, 9-21.9, 5-47.8, 12.6-47.4, 4.5-14.7, 20.1-37.8, 23.7-62.6, etc.; and in

Initial capacity, as the term has been used in these pages, denotes the average of the scores of the series of experiments constituting the first test. And since the results of all the tests, except No.'s 2, 3, 11, 15 and 16, were made up of averages of from four to ten scores of individual experiments or of series of experiments, the variation in initial capacity as here represented is not as great as would be shown had the initial scores been selected.

The result of (a) change in processes between first and final tests and (b) the variability in initial capacity is a great reduction in the strictly comparable difference-scores between the eight regular and the four control reagents.

If the number of cases is selected from the tables reproduced in the discussion of The Test Results above (pp. 106ff.), we get the following table:

Exp.	Groups	Group	Regular	1st Control	2d Control	Total
1.	4	2	2	1	0	11
2.	6	0	0	0	0	12
3.	4	4	4	1	0	12
4.	4	1	2	1	1	12
5.	3	1	4	1	0	11
6.	3	1	1	2	0	11
		2	5	0	1	
		3	1	0	1	
7.	3	1	2	1	0	11
		2	3	1	0	
		3	1	0	2	
8.	4		0	0	0	10
9.	4	2	3	0	1	12
10.	4		0	0	0	12
13.	4	2	1	1	0	12
17.	4	2	2	1	1	12
19.	5	3	5	1	0	11
Total			36	12	9	149

To interpret the table, variation in initial capacity classified the reagents in Experiment 1 into 4 groups; the only results of both regular and control reagents to fall within a single group were two of the regular and one of the 1st control reagents in Group 2; 11 reagents took the test.

time in marking out words, 170-232, 175-306. Culler's (Interference and adaptability. Archives of Psych. 1912. 3: No. 24:16) nine reagents in the

The tables of relative variation in reaction time (of Test 1) and the "Fatigue Index" (of Test 19) are omitted in this table.

The aggregate of cases in which the difference-scores fall into some group in which comparison can be made is 57 (38%) out of a total of 149.

And if the averages of tests in which the results were sufficiently irregular to be omitted, are combined with these, *out of a total of 219 difference-scores we have but 57 (26%) which are comparable.*

g. Causes of Variability

The more general causes of variability in a reagent's work were conditions of health, relative freshness or fatigue, emotional conditions, attitude toward the work of the test, etc. Incidental causes occasionally occurred such as, cold hands in reaction tests, winking at the moment of a rapid exposure, accidents in manipulation of keys, or in handling pen and paper in recording, unusual distraction, influence of preceding laboratory work (He. and Wf. in reaction to sound), mental practice (Wf. in typewriter reaction), *etc.* More specific causes varied in accordance with the nature of the work in the test, but may be described in general terms as, voluntary or undesigned shifts of the attention to various elements of the processes engaged, changes in the extent of the distribution of the attention over part-processes and their coördination, constructing of more adequate methods, and practice-effect in dropping out of the process unessential factors, in heightening sensitivity, discrimination, reproduction, habituation to distraction, and in building up habits of higher order.

To these causes are due the serrated aspect of the practice curve of a reagent in any of the tests.

The causes of variation in the results of different reagents must lie in individual variation with respect to the factors described above, and to others in addition to them. An impor-

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first group ranged in averages of the first five experiments in the typewriting practice, 20.8-49; the 7 reagents of the second group, 33.2-131; and the 8 reagents of the third group, 28-60. These few samples show the tendency which is likely to be found in any table of initial capacities in mental tests.

tant place among the latter must be given to the 'Aufgabe,' or the task held in the mind of the reagent: Simple reaction, for example, may be 'sensorial' or 'muscular'; and word-completion may involve self-imposed limitations; *etc.*

Radically different methods of work account for large differences in intial capacity or in per cent of improvement (even when based upon equal initial ability).

The low initial capacity of Sl. in card-sorting was due to marked variation in kind of work from the other reagents—his difficult map-scheme used for discriminating the cards and for locating the compartments was the prime element in the difference.

The low initial capacities of Ly. and Sl. in the typewriter-reaction were owing to different work, the prime difference being a difficult coördination of letter and key which interfered with a coördination of the two parts of the process—discrimination, and choice of reaction.

The radical difference between kinds of work was often pointed out in the discussion of Test Results and the effect upon the averages shown. Memory of sounds was effected by kinaesthetic-auditory imagery of the names, by seizing the series as chimes, or by associating the number-names with a visible series; 12-letter-rectangles were learned through a combination of kinaesthetic and visual imagery, or through representative imagery (associations). In the distraction tests (No.'s 14, 18) the difference in the effect of the distraction depended upon variable method in avoiding conflict between the visual or kinaesthetic imagery of the retained letters and the kinaesthetic imagery of the partial sums in the adding process. And the groups into which the reagents were classified according to initial ability, in the typewriter-reaction test, were shown to be valid by analysis of the kinds of work.

Great difference in per cent of improvement was also often shown to be due to difference in kind of work. Sl.'s map-scheme in card-sorting and Ly.'s difficult coördination of letter and key in the typewriter-reaction test, prohibited rapid improvement. The anomalies sometimes found belong here: such as the gain

of Ms., a control reagent, in Test 17, which was greater than that of Al. who trained in the test material for 8 days,—they did not do the same kind of work; Al. consistently gave attention to the whole card, Ms. to a limited part of it; and the gain of the same reagent (Ms.) in Test 13, which was greater than that of either of the two reagents who trained on the test material for 18 days,—she changed to the use of associations.

As to the source of the more specific causes of variation, it lies in part in the practice on the tests themselves, in smaller part in the training (for the regular reagents), but in greater part in earlier experience. Change in the process seems to be effected through the selective function of the attention, by way of adaptation. The need of a discriminating mark for the cognition of the symbols on the cards was met by the selection of map-directions, on the part of Sl., from his schoolroom experience and the relation between diameter and radius, on the oblique pair of cards, was selected from the geometrical experience of all reagents except Le. whom the pair confused; the schemes of classification of compartments in card-sorting, for Wf. and Mn., and of keys or fingers in typewriter-reaction, for Wf., were adaptations of mathematical relations; the grasping of series of sounds as chimes, in memory of sounds, was an adaptation of musical experience; Ly.'s 'sensory set' of consciousness in typewriter-reaction was selected from her training-effects in reaction to sound; and many other changes of method in the final tests were due to the selection of elements that had become prominent in experience since the first tests, often in the training of the regular reagents.

h. The Practice Curve

It was pointed out that the difference-scores of two reagents, even when initial ability had been the same, were strictly comparable only upon the assumption that the respective ways of performing the task were equally susceptible to practice-effect. The fact that scores of *different* reagents measure different processes has its parallel in the fact that scores of the *same* reagent measured different processes; not only because the

reagent changes these processes at random, by design and otherwise, in order to hit upon a more adequate method, but because *practice-effect itself involves change in processes.* This was particularly pointed out in the discussion of the Training Results (pp. 82ff.).

The scores at the beginning of Al.'s training measured letters clearly seen; at the end, letters 'matured' from 'fringe' content of consciousness. The conquest of the 'fringe' content was the means of raising the scores of Mn. and Le. by supplementing the maximum perception and retention of clearly seen letters, and was the proper practice-effect in Al.'s training. Al., however, had not recovered, by the last day of training, from the disastrous effect of this direction of effort, upon the fixing and retaining of clearly seen letters which contributed his highest score on the third day. He was working under the disadvantage of striving to effect coördination of these part-processes and had not yet succeeded.

The early scores in Rt.'s training in learning 12-letter-rectangles measured letters recorded from kinaesthetic-auditory, or kinaesthetic imagery alone (see Analysis Curve, Appendix B. Fig. 17, p. 293). Then, additional letters from visual imagery began to contribute to the score and by the 7th day they reached their maximum. From the 5th day "visual associations" began to contribute as many letters as did the visual imagery, which had maintained its level. *The scores at the beginning of the training measured letters from one kind of imagery—homogeneous letters,—at the end, letters from four distinct kinds of imagery—heterogeneous letters.*[115]

How this change in the material measured was brought about, illustrates accurately what the practice-effect involves:

Rt. at the beginning got a strong visual impression of the letters and then converted it, by pronouncing the letter-names, into kinaesthetic-auditory imagery for retention and reproduction, repeating letter-names over and over during the 10-second

[115] The transition from simple imagery to mixed or complex imagery through practice in memory work was shown by von Sybel (Zeits. f. Psych. 53:338).

interval between perception and recording. But on the first day he found that he could economize time and effort by converting the stimulus immediately into kinaesthetic-auditory imagery and by giving a rhythm to the repetition. The effort to make a strong visual impression was dropped out. This simplification of method was accompanied by a simplification of the kinaesthetic imagery itself through dropping away of the auditory component which formerly supported it. If visual imagery found place at all, it merely supported the kinaesthetic upon the same letters. The reagent found that the 10-second exposure limited the kinaesthetic method of fixing the letters adequately for recall to the first six places. But after repetition had facilitated this process through a readier recall of letter-names in the naming process, and through a more definite rhythm in fixing the letters for recall, some time was gained which permitted attention to note other letters; these extra letters were recorded from visual imagery. This was the first coördination of different kinds of imagery from each of which different letters were recorded. This two-fold coördination then gave way to a three-fold coördination in which additional letters were recorded from "visual associations." The first occurrence of the associations involved the letters CP, which as soon as seen stood for "Chemically Pure." When recording, these letters were found to be very vivid by reason of their association with the familiar phrase; and finding associations became a method. Another three-fold process developed through the habit of intensifying the visual impression of some additional letters while repeating by rote the kinaesthetic group; when recording, it was found that other less vivid letters could be recalled from visual imagery besides those which had been intensified during perception. This three-fold process consisted in the coördination of kinaesthetic imagery, intensified visual imagery, and a secondary visual imagery which seemed to persist in its own strength. By the 10th day a four-fold process was occasionally employed which coördinated all the kinds of imagery already mentioned.

Single-fold imagery was dominant during the first three

days; two-fold coördination was dominant during the 4th, 5th, and 6th days; three-fold coördination became dominant after the 7th day; and four-fold coördination appeared on the 10th day after which it supplemented the three-fold imagery when associations were not found to hold sufficient letters. The single-fold method recurred on the 9th and 14th days; both days of reduced scores (*vid.* Analysis Curves, Appendix B. Fig. 16, p. 292).

The greatest improvement as shown by the practice curve was coincident with the greatest use of the three-fold and four-fold methods; that is, with the highest coördination of the different kinds of imagery. And the rise of the curve is dependent throughout upon the increasing use of the auxiliary forms of imagery. On the 11th and 12th days, when the practice-curve first reached its higher levels, as many letters were reproduced from the auxiliary imagery as from the kinaesthetic imagery, while on the first three days less than a fifth as many were so reproduced.

Other effects of training were: (1) the method of assigning to associations favorable letters other than those occupying the usually preferred 7th and 8th places on the card, (2) the method of recording the letters held in the weakest imagery first, and (3) a more adequate coördination of the recording and reproducing part-processes so that writing down some of the letters ceased to be a distraction on account of which other letters escaped recall.

Per cent of improvement in this training evidently measures change in processes; not merely the more radical changes at the beginning, involved in adaptation to a new kind of work, but those smaller and more orderly changes which constitute practice-effect.[116]

[116] This fact of change in processes during practice is amply supported by the literature, typical references of which follow: Talbot (An attempt to train the visual memory. Am. Jr. Psych. 1897. 8:414-7) by exercising visual recall improved her memory which made more frequent use of visual elements than it had done before. Culverwell (The creation of a memory. Jr. Exp. Ped. 1911-2. 1:160-1) reports an interesting case of improvement through practice in changed mode. Change in processes during practice was shown in reaction-time to words by Berger (Ueber den Einfluss der Uebung auf geis-

Practice-effect in the tests is a source of variability in the test-averages of different reagents. It was not operative in

tige Vorgänge. Phil. Stud. 1889. 5:170-178); in simple reaction-time by Angell and Moore (Reaction time: A study in attention and habit. Psych. Rev. 1896. 3:249-252); in discrimination of clangs by Whipple (An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych. 1901. 12:448); in learning paired associates of non-sense syllables by von Sybel (Ueber das Zusammenwirken verschiedener Sinnesgebiete bei Gedächtnisleistungen. Zeits. f. Psych. 1909. 53:338); and in memorizing non-sense syllables by Ebert and Meumann (Ueber einige Grundfragen der Psychologie der Uebungsphänomene in Bereiche des Gedächtnisses. Archiv f.d. ges. Psych. 1904. 4:202ff, 210ff, 228). Philippe (Sur les transformations de nos images mentales. Rev. Philos. 1897. 43:492) and Bentley (The memory image and its qualitative fidelity. Am. Jr. Psych. 1899. 11:47-8) pointed out the characteristics of instability and mutability of imagery which would affect recurrent processes in which it plays a part, and Kuhlmann (On the analysis of auditory memory consciousness. Am. Jr. Psych. 1909. 20:194ff) found that in later than immediate recall of sounds auxiliary visual imagery became more frequently the means of recall. With respect to changes in the processes of recall dependent upon degree of learning J. R. Angell (Determination of mental imagery. Psych. Rev. Mon. 1910. No. 53:70) wrote: "If I am obliged to repeat the words before they are completely learned, my recall is likely to be dominated by visual processes. On the other hand if I am allowed to proceed until the learning is quite perfect, the recall is likely to be mainly in auditory-motor terms, and the more perfectly automatized the act becomes, the more I lose the visual element. Judged at one stage of the process, I should then be set down as a visualizer; judged at another stage, I should be auditory-vocal-motor."

But the most conspicuous cases are shown in studies of learning, in which well-defined stages are related to the curve of practice:

Bryan and Harter: Studies in the telegraphic language. Psych. Rev. 1897. 4:27-53; 1899. 6:345-375.

Swift: Beginning a language. A contribution to the psychology of learning. Studies in Phil. and Psych. (Garman volume) 1906. 297-313, 304ff.

Book: The psychology of skill, with special reference to its acquisition in typewriting. Univ. Mont. Bull. 1908. 53:1-188.

Swift: Learning to telegraph. Psych. Bull. 1910. 7:149-153.

Ordahl: Consciousness in relation to learning. Am. Jr. Psych. 1911. 22:158ff.

Kline and Owens: Preliminary report of a study in the learning process, involving feeling tone, transference, and interference. Psych. Rev. 1913. 20:222-3.

Cleveland: The psychology of chess and of learning to play it. Am. Jr. Psych. 1907. 18:297.

some of our tests, but it was clearly so in others. If it was much greater in the first than in the final test, initial capacity, as expressed by the average score of the first test, is lower relatively, than in the case of about equal practice-effect or no practice-effect in the first and final tests; the difference-score will be relatively too large. The extent to which this source of error was operative in our tests, as well as the frequency of practice-effect in both tests, is shown by the following table:

Tests	1	4	5	6	7	8	9	10	13	17	19	Total
a.	4	6	4	1	2	0	1	1	2	4	3	28
b.	0	5	1	0	0	2	0	0	2	2	1	13

a. Much greater practice-effect in the first test than in the final.
b. Practice-effect in both tests.

In these eleven tests there were 125 difference-scores; 28 (22%) of them are too large because of the greater practice-effect in the first test; and practice-effect occurred in both first and final tests in 13 (10%) cases.

The distribution of the cases over the reagents is as follows:

Regular	a.	b.	Control	a.	b.
Mn.	2	3	Ms.	4	0
Le.	4	1	Wf.	2	0
Rt.	2	1			
Sl.	2	0			
Ly.	2	1	—	4	1
He.	2	1	—	2	1
Cr.	1	2			
Al.	1	2			

To be safe in the comparison of difference-scores, such tests should be chosen as are free from the rapid practice-effect of adaptation, or training should continue until initial efficiency is more stable and its quantitative expression more reliable.[117]

i. General Effect of Special Practice

After seeking to avoid error by making the difference-scores as nearly as possible fairly comparable, our quantitative data

[117] For further discussion of this matter, see p. 221f.

for generalization upon the general effect of special practice of the trained reagents are greatly reduced; and in view of the fact that even they are not decisive, our generalizations must remain statements of probability.

With this caution in mind we may examine the cases in which training-effect seemed to show itself in improvement in the tests. These cases are collected in the following table:

Training	Reagents	Tests
Tachistoscopic	Mn.	1, 2, 4, 6, 7,* 9, 10.
	Le.	5,* 8.
	Al.	3, 4,* 8, 9.
Learning 12-letter-rectangles	Rt.	1,* 5, 6, 8, 9.
	Sl.	7, 10.
Reaction to sound	Ly.	4,* 10, 13.
Memory training	He.	4,* 6, 9, 17.
	Cr.	4,* 5, 6, 17.

*These cases were influenced by greater practice-effect in the first test.

Common elements in part-processes, or in modes of attention, are not difficult to find:

Training on the tachistoscope involved:
quick perception (shared by tests 2, 3, 4, 5, 6, 9, 10),
keen momentary attention (shared by tests 1, 6, 7),
reproduction of imagery (shared by 4, 5, 6, 7, 8, 9, 10),
coördination of part-processes (shared by 1, 4, 5, 6, 8, 9, 10).

Training in learning 12-letter-rectangles engaged
quick perception (shared by 1, 5, 6, 7, 8, 9, 10),
rapid kinaesthetic processes (shared by 8, 9, 10),
apperceptive grouping (shared by 9, 10),
reproduction of imagery (shared by 5, 6, 7, 8, 9, 10).
keen momentary attention (shared by 1, 6, 7, 8, 9, 10).
keen continuous attention (shared by 5, 8, 9, 10),
coördination of part-processes (shared by 1, 5, 6, 8, 9, 10).

Training in reaction to sound involved
quick perception (4, 10, 13),
keen momentary attention (10, 13),
quick reaction (4).

Training in memory engaged
keen perception (4, 5, 6, 9, 17),

apperceptive grouping (9, 17),
reproduction of imagery (4, 5, 6, 9, 17),
continuous attention (4, 5, 6, 9).

The probable cases of general effect listed here do not constitute a complete list for which there is quantitative evidence, for cases in which great improvement was in part contributed by change in method were set aside; as may be illustrated by two cases of Mn. There is little doubt that she brought to the test on learning 12-letter-rectangles great advantage from her tachistoscopic training, yet her gain (64%) is set aside because of a radical change in her method induced by her training; there is no doubt at all that she improved in her training, yet her gain (147%) in the test identical with it was for the same reason set aside.

The requirement of setting such cases aside, it will be remembered, is made by the form into which the investigation was cast: the ostensible purpose was to test for the influence of improved conditions of attention, and scores including the advantage or disadvantage of change of method could not be used to measure difference in the capacity of attention. Apart from this requirement, however, there is another ground for discarding these difference-scores, which challenges their value; evidently their service is largely limited to determining the relative advantage of the different kinds of work.

But we do not need to rely upon our quantitative data for proof of general effect of special practice. Introspections indicate it more clearly and more certainly than difference-scores can. Not only are methods of work, and systems of imagery, transferred from one kind of work to another where they are applicable, as the methods of fixing and reproducing 12-letter-rectangles were carried over to memory of consonants serially presented (Rt.), and to digits simultaneously presented (Rt., Sl.), and as the better organization of associations in which letters from 12-letter rectangles were fixed and retained after training in memory (Cr.), but *the process of adaptation to the strange work of the test consists in the selection and application*

of elements of former experience which, when acquired, must always have been 'specific' and which as applied are always 'general.' This principle is not only true of the exceptional and somewhat bizarre cases cited to illustrate unusual variations in the scores, as Sl.'s map-directions in card-sorting, and the grasping of series of sounds as chimes, but it is true of the usual and regular processes of learning to do expertly the work of the test.

The general effect was usually advantageous, as was often pointed out in connection with discussion of change of method, under Test Results, but it is not necessarily so; Ly.'s 'sensory set' of consciousness carried over to the typewriter-reaction from reaction to sound, the attempted transference of training method by Rt. and Sl. to commercial signs presented in the method of training,[118] were disadvantageous. Wf.'s complex scheme in typewriter-reaction, and Sl.'s unwieldy map-scheme in card-sorting, will serve to illustrate the fact of negative influence.

Introspections indicate that the 'spread of training' need not be conscious,[119] as may be illustrated by Cr.'s improvement in learning 12-letter-rectangles which was largely due to better organization of the associations used to represent the letters, a prime factor in the memory-training, yet he was not conscious of applying training-effect. Indeed, *introspections in this type of experiment are not of value because they assert or deny the influence of training upon the tests, although such statements may often be true, but because they describe the processes engaged in both training and tests fully and accurately enough for the presence or absence of specific influences to be determined.*

j. Conclusion

Variability in the mental processes engaged by the reagent on any test was found to be universal; radical change in the

[118] Agreeing with the results of Sleight (*op. cit.* p. 440) that elements may not be available where the whole form will not apply. The fact seems true particularly when the coördination of part-processes has become automatic or mechanical.

[119] Again in agreement with Sleight (*op. cit.* p. 440).

processes between the first and final tests, for the ten tests in which the results were the more regular, occurred in over a third of the 166 difference-scores (*vid.*, p. 168).

Great variability in initial capacity, as represented by the average of the scores of the first test, was also universal; in twenty tables, there were but three cases in which the range of variability was less than half the lower average, 9 cases were between 100 and 200% of it, and two cases were over 400% of it (*vid.*, p. 169).

The effect of these two kinds of variability was to reduce the comparable difference-scores to a fourth (*vid.*, p. 171).

The causes of variability were general, such as health; incidental, such as accident in manipulation of a key or of cards; and specific, such as are involved in adaptation, or in practice (*vid.*, p. 171).

Great difference in the scores of an individual and great difference in initial capacity are signs of great difference in kind of work (*vid.*, pp. 172).

The source of the more specific causes of variation lies in part in the practice-effect of the tests, in less part in the practice-effect of the training, in greater part in earlier experience. Change in process is effected through the selective function of attention, by way of adaptation, and of acquiring skill through practice. Adaptation occasions the more sudden and radical changes, as abrupt change in method; skill through practice involves a more or less orderly sequence of changes depending in nature upon the task but always resulting in a marked difference in the kind of work performed in its initial and final stages (*vid.*, p. 173).

Practice-effect in the tests disturbs the quantitative results; if it is greater in the first than in the final test, the difference-score is too large. Any average which includes it and purports to measure efficiency is not strictly reliable. The extent of this source of error in 'mental tests' may be indicated by the fact that of 125 difference-scores, 22% were affected by greater practice-effect in the first test, and 10% by practice-effect in both first and final tests (*vid.*, p. 177-178).

Recognizing the inconclusive character of our quantitative results, even after the difference-scores were made as comparable as possible, we found 31 cases (7 of which were influenced by practice-effect in the first test) of probable transference of training-effect to the tests, some of which were greatly different in material and method from the training. In all, however, common elements in part-processes, and in modes of attention, were numerous (*vid.*, p. 178ff.).

Introspective data are decisive in indicating the transference of methods of work and systems of imagery[120] from one kind of work to another, where applicable, and that adaptation to the strange work of a test consists in the selection and application of elements of former experience which, when acquired, must always have been 'specific,' and which as applied are always 'general.' This also appears to be a principle of the learning-process, in which skill is attained by smaller and more orderly changes in the processes (*vid.*, p. 180f.).

Transference need not be consciously effected. Introspections are of value chiefly not because of asserting or denying it, but because they describe the processes fully and accurately enough for its presence or its obsence to be seen. And its effect is sometimes negative (*vid.*, p. 181).

As a measure of attention our tests are inadequate, and the question of transference of improved conditions of attention remains open. That our quantitative results were not more conclusive in showing the effects of training on attention may be owing, in addition to the disturbing influence of great variation in processes and scores, to certain limiting conditions under which the experimentation was conducted: (a) Change in method between tests rules out the results as a measure of change in attention; (b) our reagents were university students whose habits of attention were pretty well established by former training; (c) our trained reagents were more mature than the control reagents and were experienced in laboratory work; (d) our period of training was relatively short (six weeks, three days per week); (e) our tests could not be long enough to give a reliable measure of initial ability, because of inter-test

[120] In agreement with Fracker (*op. cit*, pp. 90ff.).

practice-effect; and (f) adequate introspections were limited almost wholly to the trained reagents.

The contribution of the experiment lies principally (1) in revealing the nature and the extent of variation in mental processes, both between different reagents and with an individual reagent, which may be expected when such 'tests' as ours are given under favorable laboratory conditions to intelligent young men and women; (2) in showing how such variation affects the scores; and (3) in offering suggestions toward improvement in this type of experiment.

The interesting question of how statistical method is affected by these considerations is discussed later (pp. 219 ff.).

2. Experiment on Reproduction

The purpose of this experiment[a] was (a) to supplement the Experiment on Attention by a more intimate knowledge of the factors of variation, through greater refinement of introspection and analysis, and (b) to set the conditions to test for a subtle but definite 'spread of training.'[121]

To meet the former aim, tests were chosen or devised which offer opportunity for introspection separately upon the successive 'moments' into which they naturally fall, or for fuller description of the processes used in acquisition and reproduction by reason of the material used in them.

To meet the latter aim, the tests and training were arranged to exclude the transference of methods of work or of systems of imagery, such as belong rather to the grosser and more radical changes in work, due to what was termed "adaptation," than to those smaller and more orderly changes which constitute practice-effect proper.

It will be remembered that the most definite cases of the general effect of practice which came to notice in the preceding

[a] Performed during the year 1911-1912.

[121] For the distinction between 'Spread of Training' and 'Transference,' see footnote to p. 225, and the text on p. 230.

experiment were of the nature of 'transference,' but that there was also some indication of 'spread of training'; and that it was this latter sort of general practice-effect that was found in the earlier experiments on Marking-out Words, Discrimination, and Reaction with Discrimination and Choice.

The susceptibility to improvement of the capacity to 'mature' and reproduce weak imagery in the tachistoscopic training, in the Experiment on Attention, suggested reproduction of imagery as the work of this experiment.[122] Consequently, tachistoscopic and memory tests were devised and made to differ radically in method and material from the training, in order to avoid 'transference' and to invite 'spread of practice'; a further test which differed from the training but slightly in material, and method, was included to determine if so slight a difference might cause interference.

The training chosen was sound discrimination, and in order to insure practice in reproduction of imagery of some sort, the time-intervals between the two sounds to be discriminated were varied between 7 and 60 seconds, and series of sounds were made to vary widely, as a whole, in intensity.

The tests were designed to measure the capacity to reproduce imagery occasioned by the presentation of materials of different

[122] This process, or group of processes, so far as it lies above the threshold of consciousness, may be represented by a tension of attention under the influence of 'determining tendencies' analogous to the experience of recalling a name that seems close but delays in coming; conceivably, however, it also takes place wholly under the threshold, operates in part from "Unconscious psychical stimuli" (Lipps: Grundtatsachen des Seelenlebens, S. 125), involves as subtle processes as the "unconscious associations" reported by Scripture (Ueber den Associativen Verlauf der Vorstellungen. Phil. Stud., 1892, 7:78, 136), Jerusalem (Beispiel von Assoziation durch unbewusste Mittelglieder. Phil. Stud. 1894. 10:323-5), and Thomas (Ein weitres Beispiel. Zeits. f. Psychol., 1896, 12:60). *Vid.* Footnote on p. 87. Statistical evidence of the influence of subliminal impressions upon judgment is to be found in experiments in discrimination (where Right Cases fall off regularly with the magnitude of D) (*vid.* Appendix D, p. 299, and Peirce & Jastrow, quoted by Donaldson in The Growth of the Brain, p. 292), and has been reported from experiments on Guessing by Sidis (Psychology of Suggestion. 1898. 168-171) and Stroh, Shaw and Washburn (A study in Guessing. Am. Jr. Psych., 1908, 19:243-245).

It is perhaps not necessary to point out that provision for introspection in this experiment is for other purposes than for a direct determination of the presence of these subtle processes or of increase in their efficiency.

kinds, and the training was designed to develop greater power in reproduction of imagery of a certain simple kind.

The method of experimentation was the same as the preceding. Three groups of reagents took the series of tests before and after an interval of from five to seven weeks. The first group took training during the seven weeks; the second group took all the tests before and after a free interval of five weeks; the third group took but one pair of tests each before and after a free interval of five weeks. Each pair of tests was therefore taken by three trained reagents, three control reagents who took the other tests also, and two control reagents who took no other tests.

The trained reagents (Hs., Wn., Rt.) were seniors in Psychology, English and Education, respectively, who were doing advanced laboratory work in Psychology. The first group of control reagents (Al., Hhs., Br.) were a freshman and a sophomore in Psychology, both pursuing elementary laboratory work, and a freshman in Economics who had no laboratory experience. The second control group (Ck., Pn., An., Ty., Dn., Hn., Hd.) included five seniors, one sophomore, and one freshman, representing the German, History, Education, Economics, and Pre-Legal departments of the university.

a. The Tests

Test 1. *Recognition or choice of one of two letters.* The purpose of this test was to give a measure of the liability[123] of reproduction. The apparatus was the same as that used in the Tachistoscopic test (No.17) of the preceding experiment. The method was (a) to expose a 12-consonant-rectangle 0.1 Sec., (b) after a 3-sec. interval to expose two letters printed like those printed on the rectangle, one of which was to be chosen by the reagent as having been on the card and to be recorded in the section of a ruled form corresponding as nearly as possible to its position in the rectangle, (c) to time with a stop-watch the interval between the exposure of the two letters and the vocal choice of one of them. Rectangles were presented at the rate

[123] For use of this term, *vid.* Külpe: Outlines, p. 197.

of one a minute. Fifty experiments constituted the test. All judgments carried an index of one of four grades of certainty as to the letter's existence on the card and as to the position in which it was recorded. Introspections were made upon four different intervals or moments of the experiment: (1) From "Ready" to the stimulus, (2) Perception, (3) On the interval of 3 seconds between perception and the appearance of the two letters, (4) The moment of recognition or choice.

The two letters shown for choice were so selected that they were distributed evenly over the 12 spaces of the card, that each letter was on the card one-half times as often as it was exposed for choice, and that it occupied the second position as often as it did the first in the presentation for choice; thus it would be possible to learn if any part of the card is favored in perception, if there were favorite letters, if the right or left letter presented for choice is favored, all of which would be sources of error, and under the conditions of the experiment would tend to bring the score of R cases toward the probability figure of 50%; Reproductive tendencies would be shown by the excess over 50%. Fifty experiments constituted the test.

Test 2. *Reproduction and recognition of letters on 12-letter-rectangles.* The apparatus was the same as that used in the preceding test. The method was only slightly changed from that of Test 17 in the Experiment on Attention. 12-Consonant-rectangles were exposed 0.1 seconds; 10 seconds were given in which to record the letters perceived; the card was then re-exposed for 15 seconds while the reagents recorded in pencil other letters recognized as having been seen but which failed to be recalled. The rate of experiments was two minutes. Introspections upon process and imagery were written and the following intervals of the experiment were treated separately: (1) From "Ready" to stimulus, (2) Moment of perception; (3) Upon the interval before recording, if there was one; (4) Interval of recording; (5) Interval of recognizing further letters. Twenty experiments constituted the test.[124]

[124] See Appendix C, p. 295, Method "Text (2)," for values used in scoring the results.

Test 3. *Discrimination of sounds.* The same as No. 7 in the Experiment on Attention; the same series of intervals were used (*vid.* Appendix B. Fig. 7, p. 290) and the stimuli were given with the same instrument—the sound pendulum. There were 10 series, of 9 judgments each, in the test. Introspections were taken on the process. The per cent of R cases was to constitute a measure of the sort of reproduction upon which training was taken; it being assumed that some sort of reproduction of the first stimulus, or of some function of it, was necessary to render judgment upon the second.

Test 4. *Memory for visual symbols.* Reproductive tendencies could be measured here by the amount of correct reproduction from a single presentation, and by the number of repetitions necessary to learn completely a series of 12 symbols; both measures were attempted. The Müller and Schumann memory apparatus was set at one revolution in 44.5 seconds, which presented the symbols at the rate of 1.07 seconds. And when the series was repeated, presentations came at the rate of 44.5 seconds, leaving an interval of about 33 seconds between the end of one and the beginning of another. The number of revolutions was recorded by the apparatus. The symbols were of the same kind as those used by Ebert and Meumann,[125] one series of symbols resembling notes of music with the flags variously located; the other, of symbols resembling sickles, both elements changing in absolute positions and in relation to each other.

The first part of the experiment consisted in reproduction of as many symbols as could be remembered from one presentation each of two series of six symbols; the second part, of learning two series of 12 symbols by heart.

b. The Training

Three 4th year students (Hs., Wn., Rt.) took the training in Sensible Discrimination of intensities of sound, which extended over a period of 48 days and consisted of 31, 59, 60

[125] Archiv f.d. ges. Psychologie. 1905. 4:49; samples of these forms are also illustrated by Thorndike: Educational Psychology, vol. II, p. 369.

series, 9 judgments per series, taken upon 7, 11, 13 days, aggregating 279, 450, 540 judgments respectively for Hs., Wn.. and Rt. The training was taken between 2:30 and 3:30 p.m., and continued about 45 to 55 minutes. The room during the experiment was kept closed and much darkened, and the reagents kept their positions constant, about 4 meters from the source of the sound, with their backs toward it. They took the training together and secured privacy at a long table by partitions of wooden screens.

The sounds were produced by dropping steel balls from magnets upon a steel block, by the use of Krueger's "Fall-phonometer."[126] Manipulation was noiseless. The weights of the pairs of balls were:

1.	5.56	grams
2.	8.33	"
3.	11.86	"

and the heights from which they fell, and their relative intensities of sound were:

Intervals	cm.	Intensity
9	96	1.78
8	84	1.55
7	72	1.33
6	63	1.17
5	54	1.
4	47	0.87
3	40	0.74
2	35	0.63
1	30	0.56

These steps in intensity are about one-half a noticeable difference.

The 54 cm. fall was used for the norm, and it with all the rest for variables; but by using the three pairs of balls, three norms of varying intensities (1.00, 1.50, 3.13), with their corresponding series of variables, were obtained. Judgment was given upon the second sound, and the latter was the norm as often as it was the variable. The time intervals between the two stimuli were equally distributed over 7, 15, 30, 60 seconds.

[126] Similar, in principle, to illustration in Wundt: Grundzüge d. Physiol. Psych. (5te Auf.) I: 512.

These changes in intensity of the norms and in sequence of variable and norm were intended to prevent an easy classification of the first stimulus and to favor its being held in some sort of imagery; and the temporal intervals were made various lengths to make the retention or recall of that imagery necessary, and to facilitate a checking up of this fact by comparison of the number of the Right and Undecided cases for the various intervals. The method was that of constant difference, Right and Wrong Cases; procedure without knowledge.

c. Training Results

(1) *Processes*

Hs.

At the beginning and throughout the training Hs. held the auditory image of the first stimulus, or brought it back with more or less effort, and compared it with the auditory sensation of the second stimulus (1, 32). But there were variations from this general method:[127]

[127] In the deviations from the simple direct comparison of auditory imagery which resulted in the training-series of these reagents, it is possible that reproductive processes of some sort found place. Whether the simple auditory impressions were supplemented or actually replaced by complicated auditory imagery or imagery from the other modalities (visual, tactual, kinaesthetic), or comparison was dispensed with in 'free' judgments, it would seem that imagery representing the first stimulus, or an organic reaction to it, mediated judgment. That these deviations are frequent, results largely from the fact, pointed out by Whipple (An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones. Am. Jr. Psych., 1902, 13:259), Slaughter (A preliminary study of mental images. Am. Jr. Psych., 1902, 13: 526ff), Kuhlmann (Problems in the analysis of the memory consciousness. Jr. Philos. Psych. & Sci. Meth., 1907, 4: 5ff), and others, that the auditory image is not simple and that it sometimes loses itself in its other-modal or organic constituents; and partly from the impulse, insisted upon by Woodworth (Non-sensory components of sense perception. Jr. Phil. Psych. & Sci. Meth., 1907, 4: 169ff), to clothe the sensory impression with ideational, perceptive, or emotional attributes. Bentley (The memory image and its qualitative fidelity. Am. Jr. Psych., 1899, 11:7), quoting Külpe, reminds us that reproductions are not weakened copies of sensations, that reproduced sensation is schematic, needs aids (words, movements, organic sensations, feelings) to complete recollection, and adds that these aids may become the real vehicle of retention.

Sometimes the image of the first stimulus is overcome by other imagery or by distraction: In one instance visual imagery of E manipulating imaginary apparatus crowded it out, after which it was recalled (1). When she was nervous or tired the auditory image was apt to get away, especially during the longer intervals (18, 25); then she was particularly conscious of distraction—wind whistling by the windows (26), the stop-watch ticking (31), a throbbing noise down stairs (55) which rendered the renewal of the image very difficult or even impossible. "Lost image entirely . . . was going to judge '?' when it returned and I was quite sure that my judgment 'greater' was correct" (22:5, Norm-Variable 9, 60," Right).

Instead of comparing the image of the first stimulus with the sensation of the second she sometimes had the feeling of converting her image of the first into sensation and of comparing sensations (1), or in uncertainty she compared images of both (26:8); occasionally she interpreted intensities as qualities of pitch and translated tonal imagery into intensity (14, 46); she also based judgments on extraneous imagery as "the feeling in the hands of noise from wooden blocks" (29), and other kinaesthetic images in hands and arms (32:3, V3N—15"). In some series she did not try to hold the image of the first, but often brought it back after the second stimulus was received (36, 41). In some cases she made 'free' judgments: "I lost the image entirely, yet when the second stimulus came it was very clearly 'greater' . . . it was startlingly loud" (39:2,—NV8—60"—R); "I could not bring back image of the first stimulus, but I was certain that the second stimulus was 'greater'; I think I judged more by the way it startled me than by anything else" (42:1,—NV7—60"—R).

The judgment 'like' sometimes meant that (1) the "sensation exactly fits in with the retained or renewed auditory image" (1), and is given with a feeling of certainty (21); and (2) the identity is doubtful (26).

Introspective notes as to certainty in a series correlate with the number of R judgments (28, 29).

Relief was felt when the intervals were short; the effort to

renew and strengthen the image of the first stimulus is spared (27:9).

Her training was taken under trying circumstances, occasioned by events not connected with her university work, which made her very nervous and given to abstraction. She omitted series 3-17 and 47-49 inclusive.

Wn.

Particularly at first and somewhat all through the training Wn. retained or revived images of the first stimulus in order to pass judgment upon the second; comparison however was difficult: "I seem to compare the first stimulus I have retained through images, with the second stimulus as soon as I hear the latter. When I have tried to compare them both as images I have found great trouble in keeping each clear in my mind; they have tended to overlap each other" (3). This difficulty in comparing images is mentioned several times (6, 8). Nevertheless to pass judgment upon the sensation of the second stimulus, the image of the first seems necessary: "I find that if the first is not in my mind as one image or another when the second is sounded, I have great difficulty in comparing the two. It requires constant attention to keep it there,"(6). The holding or reviving images is mentioned in series 1, 2, 3, 14, **17**, 20, 21, 22, 28, **38**, 41, 48. It was resorted to in the heavily typed series (17, 38) upon inability to classify the first stimuli or to attribute to them a personal quality.

The images are strong just after the first stimulus has sounded, but soon fade (2), are very hard to retain (6) or to revive after they have disappeared. Often they are recalled by the second stimulus (7, 12, 26).

The imagery seems rarely purely auditory. It is usually auditory and kinaesthetic, the latter taking the dominant rôle, especially in reviving a waning or lost impression (2, 3). In this the throat, head, and hands, are chiefly instrumental (1, 4, 7, 11, 13, 14, 20, 28, 41). Sometimes the kinaesthetic image is based on a "singing" of the first stimulus, intensity being interpreted as pitch (15, 28, 41, 49); rarely is the pitch held

in auditory imagery of another's voice (43, 48). Occasionally the sounds are interpreted as 'stronger' instead of 'greater' (4); and value is given in terms of "sensations of being struck" (1). Judgments were sometimes based upon the "startling effect" (3, 4a), or a "sensation of surprise," (5). Visual imagery played some part but was usually recognized as a distraction (4, 13); sometimes, however, as an aid (13, 14, 20, 27). It took various forms: "a piece of steel being snapped" (1, 13, 20); "E working with the apparatus" (4, 11, 14, 27); "a piece of steel hitting a bar of iron" (4); and such as attended associations involved in attributing personal qualities to the stimuli (43).

Other modes of passing judgment developed early and continued throughout the training. The beginning of the method of classification resulted from a noted "familiar" quality of the first stimulus as a sound that was heard before and is now known (8, 9, 36), and a comparison of the first stimulus with preceding first stimuli (10, 11). This led to classification as "very loud," or "very soft" (10, 11, 14, 18), which developed into a method (20, 30, 31, 41, 49): "I have developed quite a system of classification of the first stimulus as 'very large,' 'large,' 'small,' 'very small,' etc., so that I have no difficulty in recalling it upon hearing the second. I do not even have to think of it in the interval when the first stimulus is very decided one way or the other" (30). The first stimulus was then retained in verbal-motor imagery. Sometimes this method failed, however, and she had to fall back upon auditory-kinaesthetic imagery (33). Upon the break-down of this method, another was developed, suggested probably by an early instance (13:6) in which a loud stimulus brought to mind a very aggressive man of her acquaintance. Qualities of personality were conferred upon the first stimulus (13, 35, 36, 37): "From classifying the stimulus in a general way as 'very great,' 'great,' etc., I have come to attributing qualities; as, aggressiveness, timidity, power, weakness, etc. I find that by doing this I can remember the stimulus easily when I want to compare it with the second stimulus and need not think of it during the interval, as is the case when I try to retain it by image" (35). Sometimes, how-

ever, the stimulus failed to suggest personal qualities (38); "In such cases I fell back on the images, auditory-kinaesthetic, for a comparison, and was usually able to recall them" (38).[128]

The obvious economy of these two methods in the longer intervals of 30″ and 60″ is probably responsible for their use.

'Free' judgments were seldom made (26.3).

'Like' judgments were usually based upon "similar effects—same kind of sensations" (1), or "the same sensation of surprise" (4).

The short intervals (7″, 15″) were a relief (10), the long ones difficult (18, 23, 47), especially because the retained imagery may not belong to the last experiment.

The heavier balls were also a relief (16, 22, 46); the weaker sounds were hard to retain and hard to classify (33).

When the norm was the first stimulus it was often thought to be varying (17).

Emotional factors probably played some part in determining judgment: Sometimes the second stimulus was anticipated (5); reagent was worried because there were so many 'less' (20, 43) or 'greater' (24) judgments occurring in the series; or upon giving several 'like' judgments she tried to make the rest either 'greater' or 'less' (32). Conferring personality was an "interesting" process (36) and may have urged attributes not appropriate.

The 'type' as shown by an assembling of the data is verified by introspection: "I am surer of 'less' than of 'greater' judgments" (5). The R judgments for the cases in which the second stimulus was 'less' greatly exceed those of the cases in which it was 'greater.'

Rt.

Rt. insists that no image of the first stimulus remains during the interval (1, 2, 4): "In fact if I try to keep it in mind I am not sure that I succeed as well as when I don't try to do so" (1); but "an idea of the intensity of the first stimulus remains—though not in auditory imagery" (1:7). "I do not carry the image over the interval; I do carry a sort of estimate of the

[128] That methods and standards of judgment alter in training was shown by Whipple's reagent O. (Am. Jr. Psych., 12:448).

comparative loudness of the first sound: I cannot say just how I form the estimate" (5). At the beginning of the training, therefore, he began to classify the first stimulus which relieved him of carrying an auditory image. But there were times when the image of the first stimulus was distinctly recalled just after the second was received: "On the appearance of the second sound there must be a recall of the 'idea' of the loudness of the first sound, and I think the actual sound arouses an auditory image of the first" (36).

As the training progressed, judgments were confidently given when no image or idea of classification was present (28), and it became difficult to introspect (31). The following is a description of the process written after the last series:

"I have a 'mental estimate' rather than an auditory image of the sound. There must be a vague fleeting imagery with this 'mental estimate' for if the interval is long this estimate is less definitely placed, is more elusive and fleeting and vague. A sort of 'stock pattern' of degree of loudness remains. This concerns only the interval. On the appearance of the second sound I am more able to judge than I expect to be" (49).

There are many protests against the long intervals (1, 2, 3, 10) the reagent claiming that he loses attention; this would seem to indicate an effort to carry imagery along.

Judgment was usually given quickly or upon the appearance of the second stimulus (2, 3). The most satisfactory state of the attention was not the highest (2), and the reagent complained that it was often poor (4, 6) and often that the sounds seemed vague (13, 14). Distraction was often noticed (5, 18, 26, 27, 35, 41).

The judgment 'like' merely meant no perceptible difference (1:8, 4:6).

The reagent's 'type' is verified by his introspection upon the last day: "The long interval I feel makes the second sound seem louder. The first is fading in intensity and clearness and is becoming flitting in its recall. . . . There is either an unusual number of judgments 'greater' or else I have a decided preference for them in series 48 and 49."

(2) *Quantitative*

In reckoning Right and Undecided cases (a) judgments upon D=o are discarded,[129] (b) 'Doubtful' and 'like' judgments are aggregated as Undecided; (c) per cent is reckoned upon the total number of judgments upon D>o.

With the intermediate weight of ball a series of judgments yield a slightly greater per cent of R cases when the fall-phonometer is used (as in the training) than when our test series is given on the sound-pendulum (as in Test 3). The following table gives the results of Rt.: (80 judgments each).

Sound Pendulum		Fall-Phonometer	
R	U	R	U
62.5%	27.5%	65.0%	22.5%

All other conditions remaining the same, a greater per cent of R cases occurred (a) when the absolute intensities were greater (heavier balls being used), (b) when the time-interval between the stimuli was 15″, (c) when the second stimulus is the less, for Hs. and Wn.; when it is the greater, for Rt.

From the following table, showing the number of R cases in 96 judgments on each time-interval, in seconds, it appears that "imagery" of some sort was more or less used:

	7″	15″	30″	60″
Hs.	46	57	48	43
Wn.	51	61	54	59
Rt.	63	68	61	54

The 7″ interval was not sufficient for the imagery to become settled. The imagery seemed to dim with the flight of time; only for Wn., who used classification more consistently—an indirect method,—was the longest interval as favorable as others.[130]

[129] *Vid.* p. 43, footnote.

[130] The indication of the dependence of judgment upon memorial factors becomes more definite if we separate the judgments according to the relation of the intensity of the second stimulus to that of the first. Assuming, from the work of Ebbinghaus and others, some of whom are noticed below, that the memorial factor dims with time, one should expect (1) Overestimation of the second stimulus, (2) A falling off of Right Cases with time, in the gross averages (as is shown in the table above), and (3) upon segrega-

If the R judgments of the training are aggregated for each of the reagents respectively, their relative efficiencies may be compared: Hs. 50.4%, Wn. 58.6%, Rt. 64.1%.

A peculiarity of the training is that instead of improvement

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ting the data as suggested, a general restriction of this decrease in R cases to the group in which the second stimulus is less than the first. This third expectation is fulfilled in the following table (Per cent of judgments reckoned upon all judgments upon D>o):

			7″	15″	30″	60″
$S_1<S_2$						
	Hs.		23	55	36	53
	Wn.		33	58	54	69
	Rt.		63	71	77	71
			—	—	—	—
		Avg. %	40	61	56	64
$S_1>S_2$						
	Hs.		69	56	57	34
	Wn.		71	67	63	54
	Rt.		69	71	50	40
			—	—	—	—
		Ave. %	**70**	**65**	**57**	**43**

The first expectation enumerated above, is met by all reagents when the stimuli were given 60″ apart, and by Rt. in gross averages. It is opposed by 'Type' in the shorter intervals for Hs. and Wn. Another influence to veil in slight measure the fulfillment of these expectations is the presence of 'absolute' or 'free' judgments, shown by all reagents in excess of R cases in Order N—V over Order V—N; it amounts to about 7% of all R cases on D>o.

Our results conform pretty well with the literature. The over-estimation of the second stimulus (the Fechnerian Time-Error—*vid.* Psychophysik I:88) has been found with musical tone by Wolfe (Phil. Stud. 3:556), with intensities of sound by Starke (Phil. Stud., 3:270ff), Merkel (Phil. Stud., 4:117ff), Lehmann (Phil. Stud., 7:205), and Tschisch (Zeits. d. Psychiatrie, 1896), with memory for passive movement by Schukowsky (Zeits. d. Psychiatrie, 1899), with discrimination of shadows by Gerwert (Zeits. d. Psychiatrie, 1899, No. 8), and with discrimination of shades of gray by F. Angell (Phil. Stud., 19:5).

A falling off of R cases with increase in time between the stimuli is shown by Wolfe (*op. cit.* p. 569), Tschisch (Dritter Int. Kong. f. Psychol., 1896, p. 103), Gerwert (*op. cit.*), and F. Angell (*op. cit.* From Table III, pp. 12-13).

The general restriction of this falling off of the R cases with time to the group $S_1>S_2$ cannot be well illustrated from the literature for the reason that this group cannot be segregated from the other ($S_1<S_2$) in the tables; it is

retrogression was shown in R judgments, although Undecided judgments decreased. The following table gives the per cent of R and U cases for each third of the training:

	R			U		
	1st	2d	3d	1st	2d	3d
Hs.	....	51.1	48.8	....	33.8	30.0
Wn.	60.0	58.8	57.5	18.8	26.3	18.8
Rt.	63.8	68.8	60.0	25.0	16.3	13.8

The only improvement indicated is in Rt.'s intermediate part of the training. This may mean that no increase in reproductivity took place as a result of the training, in which case, if we may judge from the results of the single reagent in the Experiment on Sensible Discrimination (p. 45) who failed to improve with practice, no improvement is to be expected in the tests. It will be seen in the test results that in Test 3, on this same process, Rt. is the only trained reagent who shows a gain and that is insignificant in amount.

But on the analogy of Al.'s training in the Experiment on

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shown, however, in the data of Table III in F. Angell's research on the Discrimination of Shades of Gray (*op. cit.* pp. 12-13) which we segregate and present in per cent of R cases as follows:

		5″	15″	30″	60″	Avg. %
$S_1<S_2$	Al.	61.9	60.4	67.3	72.2	65.4
	Bt.	53.5	48.2	55.7	65.6	55.7
		57.7	54.3	61.5	68.9	
$S_1>S_2$	Al.	63.0	53.7	46.4	47.5	52.7
	Bt.	67.7	70.7	65.2	55.0	65.3
		65.4	62.2	55.3	51.3	

When intervals of from 5 seconds to 60 seconds have been used between the stimuli, optimal intervals greater than 5 seconds and less than 30 seconds have been shown by Gerwert (*op. cit.*), Tschisch (Dritter Int. Kong. f. Psychol., p. 103), Wolfe (*op. cit.*), and Angell (*op. cit.* p. 5).

Influence of 'Type' was shown by Martin and Müller (Zur analyse der Unterschiedsempfindlichkeit, pp. 128-134), Kämpfe (Phil. Stud., 8:582), and F. Angell on Discrimination of Clangs (Am. Jr. Psychol., 12:72).

A good critique of the variable influences upon R cases in this type of experimentation is to be found in Martin and Müller (*op. cit.,* pp. 17ff) and in Angell's review of the same in the Am. Jr. Psychol. (11:266ff).

Attention, there may have been some change made by the training which the scores failed to show. Analysis rather than scores must be relied upon to determine this, and it was seen in the analysis of processes that change did take place.

d. Test Results

(1) *Recognition or Choice of One of Two Letters*

The method of this test favors analysis of both introspective and quantitative results for determining many of the factors of variability in the processes involved in a task which seems quite simple and definite.

(a) Introspective Analysis

If one experiment be divided into four intervals upon which introspections were recorded, the method of the reagent and the accompanying processes may be stated as follows:

1. *Interval between signal and stimulus (2 sec.).* A settling of the body into a comfortable (Al.) or a strained (Hhs.) attitude, a direction of the gaze upon the window of the screen, sometimes with the head at a slight angle (Wn.); Consciousness may (1) contain keenly the purpose of (a) seeing the whole card, or (b) a definite portion of it, or (2) the mind may be a blank (Hhs.). If perception of the whole card is intended, the center of the window may be keenly fixated or the gaze may be not so limited spatially. The trained reagents appear to have been more constant in holding a single purpose, though all reagents varied some in this respect during the 50 experiments of the test; the control reagents did more experimenting especially in regard to the extent and location of perception.

2. *Moment of perception (0.1″).* A more or less dim image of the whole card may result, but usually one line or a group of letters stand out more clearly, while the rest of the card may present some dim imagery or may appear blank. Sometimes the presentation was read (verbally) from left to right or from top to bottom; sometimes just seized as a whole, visually. The grades of clearness of the letters did not follow from the purpose, except in cases where perception was narrowed to a

small part of the card. From 2 to 5 letters were the usual number that occurred in clear imagery.

3. *Interval between the perception and the presentation of the two letters (3″).* Visual imagery was held and often read as far as clear letters appeared; effort to 'mature' dim imagery, and to locate the letters seen. Sometimes a vivid hope is entertained that certain of the clear letters will be exhibited. There was noted a feeling that more letters than those perceived would be recognized if shown (Rt.).

4. *Moment of recognition or choice.* If one of the two letters shown had been clearly perceived, it was instantly named; if neither had been clearly seen, effort was made to determine which had been on the card and one was chosen because it "seemed more familiar" either to sight or by pronunciation, because it brought back a vague image of the card, because its form was more pleasing, because of certainty that the other letter was not seen; or the choice was a "pure guess." Since the imagery was in all grades of clearness, certainty of judgment graded down from very certain to wholly uncertain. Four grades were recorded. "Very certain" was given for very clear visual or kinaesthetic or combined imagery; "Certain" for less clearness; "Not just certain" either for such imagery as would support the choice of a similar letter, or for vague imagery; "Wholly uncertain" for very vague imagery or for none. Sometimes a letter was recognized as having been seen, while in process of pronunciation (Hs.). Other cases of 'maturing' imagery adequate for recognition, concurring with the feeling of familiarity, and efficiency in recalling a vague image of the card, referred to above, are indicated by changes in choice. That vague imagery often determined undecided judgments is shown by the record of the influnce of the 1st, 2d, and 3d preceding cards.

(b) Quantitative Analysis

Analysis of the quantitative results reveals some additional factors of variation in processes, indicating further complexity of the processes engaged in this simple task, and shows in what way training of the regular reagents affected these processes.

The range of initial capacity was from 48% to 76% R cases, and its average of 61% was increased in the final test by 2%. But increase was not uniform, nor do the regular reagents show any advantage over the control reagents, and it will be made evident that these scores cannot be taken as a measure of reproduction or, in fact, of any other capacity. The first patent indication that they measure greatly different processes is the fact that the results of two control reagents are directly opposed to each other: Al. made the highest score in the first test, and the lowest in the final, losing 18%; Ck. made the lowest score in the first test and made the greatest gain (12%).

Letters were chosen by all reagents with four degrees of certainty each of which involved different processes, as is shown not only by the introspections but by the regularity of their quantitative results when the latter are aggregated:

	VC	C	NC	U
% R cases	94	73.6	56.3	49.4
Avg. time of choice	1.22″	1.47″	1.68″	2.16″
Avg. space error	0.79	1.15	1.32	1.41

The distribution of all judgments is shown by the following per cents:

14.6	18.4	21.6	45.4

Thus almost half of the aggregate of judgments was "Wholly Uncertain."

The distribution of judgments over the various grades of certainty varied some between the first and final tests for all reagents. This was caused by variability in the direction and extent of the attention, owing to the difficulty of carrying out the instructions to attend to the whole card; only one reagent (Rt.) was able to do this consistently and he complained that the unnatural effort was a distraction. It has not been stated, perhaps, that all the letters on the card in all our tachistoscopic tests fall easily within the angle of acute vision. The effect of narrowing the attention to a portion of the card was to get a few letters in great clearness at the expense of any imagery

of the rest of the card however vague, to increase the number of "Certain" choices, and to decrease the influence of 'fringe' imagery in determining R cases in "Uncertain" choices.

That the latter influence was present is indicated by the time-relations between the right and wrong cases in Uncertain choices: If the four averages containing the greatest increase in time of R over W cases, the four containing the least increase, and the five containing decrease in time, are selected and compared, we get the following table:

Increase in time	.54",	Ratio	R : W	1.40
" " "	.125",	"	"	.93
Decrease " "	.14",	"	"	.83

Which indicates that in "Uncertain" choices time was a function of R cases. It should be noted that when R cases are not influenced by 'fringe' imagery, the ratio of R:W should be 1., and that the table shows in the ratios of lower value an opposing influence which will be discussed later as the effect of preceding impressions. In "Certain" choices, of course, R cases correlate with less time.

Variation between reagents in extent of the card attended to is indicated by the location of letters in "Certain" choices: 1st line, Hhs.; 1st and 2d line, Hs., Rt., Wn.2, Ck.; 1st and 2d mainly, Al; 3 lines, Br., Wn.1.

The averages emphasize three types:

	Lines		
	1	2	3
Hhs.	24	2	1
Hs., Wn., Rt., Ck.	14	10	3
Al., Br.	9	19	8

Other factors of variation in the processes involved especially in "Uncertain" choices, as shown by quantitative analysis, are the influences of favorite letters, of similar letters, of the position of the letters exhibited for choice, and of preceding letters.

All of the reagents favored or ignored particular letters, although these letters rarely retained their special status throughout both tests, but rarely exchanged their status in the final test. This influence is verified by the fact that choice of the favorite

letter is made in shorter time, besides being shown by greater frequency in a tabulation of all letters chosen.

Partiality for the left or right letter exhibited for choice was shown by all reagents and is constant for both tests; in five cases it was as high as 1 : 2.

Influence of preceding letters was suspected when it was noted that wrong cases would frequently have been right for preceding cards, and was found by comparing the number of identical letters preceding the *recorded* letter with the number preceding the *true* letter. The aggregate shows the influence clearly:

	Preceding cards		
	1st	2d	3d
Certain choices	27.8%	5.3%	1.5%
Uncertain choices	9.4%	45.0%	-6.5%

This influence upon "Certain" choices was shown only by space error, and must have been effective through facilitating perception;[131] upon "Uncertain" choices it was shown by both space error in R cases and by W cases, and must have been effective, in the former, by augmenting 'fringe' imagery into determining influence, in the latter, by either augmenting 'fringe' imagery of a similar letter, or by persisting to the exclusion of 'fringe' imagery from the last perception.[132]

A factor working for wrong cases, especially in "Not just certain" choices, and counteracting the influence of preceding letters toward R cases in "Uncertain" choices, was the influence of similar letters. All errors in "Certain" choices were attribut-

[131] Schumann (Die Erkennung von Buchstaben und Worten bei momentaren Beleuchtung. Bericht u.d. I. Kongress f. Exp. Psychol., 1904: 36) inferred from the fact that the recognized letters were not always those most clearly seen, that the recognition of letters must be assisted by residua of previous perceptions of them.

[132] In tachistoscopic presentation of mutilated typewritten words, Pillsbury (A study in apperception. Am. Jr. Psychol., 1896-7, 8: 355, 357, 359) found an unconscious effect of preceding words upon the word-completion process; introspective report of the absence of an association determining the completion was untrustworthy. McComas (Some types of attention. Psych. Rev. Mon., 1911, No. 55, p. 33) also found, in tachistoscopic work, a determining influence from presentations given 2 min. and 5 min. earlier; content appeared to lie dormant until reported as seen on a later card.

able to this cause, and revealed as similar letters, TH, MW, DB, XK, NY, RB, PR, NK, CQ, YV, BK.

In testing for the influence of training in the reproduction of imagery upon this test we cannot use the gross scores of R cases; increase of reproduction is consistent with an increase of W cases in "Not just certain" choices because of the similarity of letters; we are consequently limited to the "Uncertain" choices, and, although they are influenced as shown above by many factors of variation, they furnish evidence that the training produced some effect.

Since the range of initial capacity was but from 43% to 50%, results may be grouped and handled with a degree of confidence. The regular reagents show a greater increase in R cases:

	First	Final	Difference
Regular	44.8%	58.1%	+13.3
Control	45.9%	50.0%	+ 4.1

Part of this increase must be due to the 'maturing' of 'fringe' imagery as is indicated by the greater increase in the time of the R over the W cases in the final test:

First test	.04″
Final test	.25″

It was pointed out above that time here is a function of R cases. This increase is not shared by the control reagents nor by one of the regular reagents (Wn.) who in her training avoided reproduction of simple imagery.

Since there was some increase of influence of preceding letters, it is possible that this influence tended, more than in the case of the control reagents, to augment the 'fringe' imagery of the last presentation in a way similar to the effect of this influence in facilitating perception in cases of "Certain" choices. If the 'fringe' material from preceding cards is not 'matured' about a nucleus of 'fringe' imagery from the last presentation, its influence would be toward W cases; and the above table indicates by per cents below probability (50%) that this occurred in the work of both groups in the first test, and it may have occurred and have been overcome by its opposing factor in the

final test. That this balance occurred in the case of the control reagents seems evident from the slight increase in the per cent of R cases, as is shown by the table above, in spite of great increase in the amount of influence from preceding cards:

	First	Final	Difference
Regular	13.3%	16.7%	+ 3.4
Control	18.2%	32.5%	+14.3

This table also shows that the control reagents were somewhat more influenced by preceding letters than were the regular reagents in the first test. The effect of the interval upon the control reagents was to shift this influence toward the more remote cards and to make it independent of imagery from the last presentation. The effect of the training upon Hs. and Rt. was to shift this influence to the more recent cards and to combine it with 'fringe' imagery of the last presentation.

(2) *Reproduction and Recognition of Letters*[133]

The results of this test furnish another forceful illustration of the worthlessness of merely quantitative treatment of 'mental tests.'

Initial capacity in recording letters from a 12-letter-rectangle exhibited 0.1″ ranged from 4.15 to 10.05 points. The three regular reagents occupy the three higher places. With one exception gains in the final test vary inversely with initial capacity. The final capacity of but one control reagent exceeded the lowest initial capacity of the regular reagents, and that exceeded by 40% the final capacities of two reagents who trained, in the preceding experiment, on this work for 18 days. Introspections offer no explanation.

The recognition part of the experiment, designed to test for reproductive tendencies too weak to reach the threshold,

[133] Experimental work justifying our selection of this test has been done by Robert Mac Dougall (Recognition and recall. Jr. Philos. Psych. & Sci. Meth. 1904, 1:229-233) who used words for his material. He found that where about a half were reproduced through recall, about three-fourths were recognized. "Characteristic differences between recall and recognition," have been more recently studied by Hollingworth (Am. Jr. Psych. 1913, 24:532-544).

was ill advised owing to the impossibility of checking reagents in their recognition and of equating their scores.

Two important facts, however, may be extracted from the results.

The regular reagent who avoided reproduction of simple imagery in her training and who was not benefited by the 'maturing' of the 'fringe' imagery in "Undecided" choices in the preceding test (Wn.) lost 6.2% while the other two regular reagents gained 7% and 5% respectively, yet her initial capacity was slightly below their's.

And the introspective evidence of variability in processes recorded in Test 17 of the preceding experiment is supplemented by similar evidence showing that this variability appears in each 'moment' of the experiment; particularly in four of the five intervals into which the experiment naturally falls: (1) In the 'Anlage' between "Ready" and the stimulus; (2) In the direction and distribution of the attention during the perception, especially with reference to the treatment of the after-image which persists after the screen has fallen; (3) In the process during the voluntary interval between perception and recording; (4) In the process of coördinating the maturing, retaining, and reproducing part-processes, during recording.

(3) *Sound Discrimination*

It will be remembered that the work of this test is the same in kind as the work of the training, the only difference being that here the sound-pendulum was used instead of the fall-phonometer (*i.e.,* the sounds were produced with wood instead of with steel), and the time-intervals between stimuli were all short (about 3″).

(a) Processes

Reagents were not shown the sound-pendulum or the manner of producing the sounds, in order to avoid the 'stimulus error' and the complication of visual imagery. But usually curiosity was evinced as to how the sounds were produced,

and in almost all cases visual imagery of imaginary apparatus was frequent in the process of discrimination.

Hs. used auditory imagery for judging, and in both tests speaks of comparing the images; in the second test she speaks of ease of judging in one series because the auditory image of the first stimulus remained in her mind without effort. But in the beginning of the second test she also compared the image of the first with the sensation of the second stimulus, only bringing the latter into imagery for comparison when the judgment was at first doubtful. She was helped by kinaesthetic imagery into which the stimuli were converted by singing the tone, by striking or pressing down or weighing with her arms and hands, etc. When the kinaesthetic and auditory bases of judgment conflicted she speaks of following the latter. She had considerable visual imagery which was regarded as a hindrance: of the experimenter holding a hammer and knocking on the table, of a scale for distributing intensities,[134] and of steel balls falling. Another distraction was the anticipation of the second stimulus. An affective image, as of knocking in the back of the head, is spoken of at the beginning of the first test; and an auditory image of her own voice singing the stimulus occurred in the second. The interval of training seems to have diminished the visual imagery and other distractions, leaving her with the general method of holding the auditory image of the first stimulus as a basis of judgment upon the impression of the second or of comparing with the image of the second in case the difference seemed doubtful.

Wn. also has varied imagery as bases of judgment; but her kinaesthetic imagery is perhaps predominant, affective imagery following, then visual and auditory. She speaks several times in her introspections in the first test, of comparing images; sometimes these are a combination of auditory and kinaesthetic; and in case of doubt she reviews them over and over in her mind. Her kinaesthetic imagery began immediately and continued throughout: She tried to remember by kinaesthetic

[134] *Cf.* Angell, F.: Phil. Studien. 1892. 7:414-468.

image in the mouth, head and arms (1 : 1), pressed the teeth together (1 : 2), tried to sing the stimuli (1 :3, 2 :7), nodded head (1 :10); and several times the stimulus could be recalled only through kinaesthetic imagery (1 : 6, 7). She had affective imagery: felt knocks in the head (1 : 1), "feel the sound before I hear it; if 'feel' and 'sound' do not agree I make both intensities with my arms; this aids my judgment more than auditory images" (1 :5). Distracting influences were the visual imagery of woodpeckers and trees (1 :1), of E with a little wooden peg (1 :2) or hammer (1 :4), of toy men hammering a block (though she thought this helped) (1 :6); anticipation of the second stimulus (1 :3); bothering about the instrument (1 :3); bothered because of so many "greater" judgments (1 :8) or "less" judgments (2 :7). The interval of training seems to have qualified her to give judgment upon the second impression; she says she compared auditory image with auditory impression (2 :1). Her kinaesthetic imagery continues, moving hand as if it held the hammer (2 :7); and so does the affective: "feel the little hammer in my head and myself knocking with it" (2 :2). The visual imagery does not seem quite so frequent. Although the interval was not over a few seconds, she felt that she makes the sounds more and more alike as she recalls them (2 :6), which indicates that voluntary strengthening of the first stimulus may account for her type which was shown in her training results.

Rt. from the first protested that he carried no image of the first stimulus over to the second (1 :1, 3); but that he "rethinks" if not "re-images" it (1 :1). When he thinks "just how loud was that sound?" and dwells upon its intensity, he becomes confused in his judgment upon the second (1 :4). An attentive attitude less than maximum was most satisfactory (1 :3, 4, 5). The probability of a symbol of opposite meaning following several like symbols in succession in a series, he thinks, may have occasionally influenced his judgment in doubtful cases (1 :7). In both tests he was bothered by rhythm which would run through his head and tend to make the second

stimulus louder or weaker than it really was (1:8, 9; 2:4). The effect of the training was to make these 'wooden' sounds seem "novel"; he was very uncertain of his judgment in the first series of the second test, and his score was low. But in his 3d series he underscored four out of his nine judgments, showing that confidence soon returned. And near the end of the test he says: "The whole of the work today is so much easier to follow, with the short [temporal] interval [between the stimuli] (2:8).

Al. thinks that she compares impressions that seem to be in her head, in making judgment (1:1); she attentively fixes the first and waits a few moments after the second stimulus has been received before judging. But by the middle of the first test she remarks that it does not take so long to judge (1:5); even then, the first sound seemed to be an impression in her head. After the interval the clear differences were judged upon the receipt of the second stimulus; the smaller differences, after a few seconds of comparison (2:1-3). Later in the test she felt the effect of practice (2:4, 6) when the differences were clearer and judgment was more readily given. The second test seemed much easier.

Hhs. made judgment immediately upon hearing the second stimulus; seems to have classified his sounds as light, medium, harder, (as of striking a board) (1:7, 2:4) and also without using the class-names (2:8-10). He had visual imagery of a metronome (1:6), and of some one striking a board with a small mallet. Thinks the second test a little easier, and that there were more clear intervals in it. Shows considerable practice-effect in the first test: 3, 3, 1, 4, 3, 5, 5, 5, 5, 6.

Br. uses as a basis for judgment the effect the sound works upon him (1; 2:1). To this he added a sort of a classification. The second test seemed much easier than the first; more clear differences.

Ty. thinks she compares auditory images, at first (1:1), which when clearly different are outside (1:4), but when not, they are brought inside the body and converted into a "tactual"

image in the eyes and nose (1:4). She has some kinaesthetic imagery in the arm as if striking (1:4, 2:3). After the interval there is some change: she weights the after-images of the stimuli, if their difference is slight, in her ear (2:2); and has kinaesthetic images in ear and throat (2:6) and chest in breathing (2:6); sometimes of humming the stimulus (2:6) or tapping it; and feels that the after-image of the second stimulus is louder than it should be (2:5); the change in general was toward kinaesthetic and possibly affective (tension in the ear) conversion.

Dn. says that in comparing sounds his "mind was concentrated on a point inside the ear" (1:2); he compared controlled exhalations of his breath, like carrying the tone of a piano in the roof of the mouth; less intensity, smaller volume of breath breathed out. He also classified sometimes. In the second test the same method was continued, except that in breathing the tone the tension of the throat muscles was taken into account; and it was supplemented by kinaesthetic imagery of the head and arms as in nodding or striking; of the toes, as pressing down for a heavy tone, raising for light (perhaps transferred from piano-playing).

These analyses indicate clearly that for the unskilled reagent discrimination of intensities of sound is a very variable process. Practice may not lead to improvement, as was shown by our trained reagents, and is verified here by Ty. and Dn., and the chief causes of retrogression are indirect methods of dealing with the stimuli; Wn, Ty., and Dn. are the clearest examples of this.

A point of interest is that the 'wooden' sounds caused the trained reagents some interference after their habituation to the 'metallic' sounds of the training: Rt. recorded that these sounds seemed "novel" and he was consequently very uncertain in his judgments, in the beginning of the second test; and the sum of R cases in the first two series in the final test was lower for each of the three reagents than in the corresponding series in the first test. By the third series, however, the interference had been overcome.

(b) Scores

Initial capacity ranged from 48.8% to 76.3% R cases. The three regular reagents occupy the three higher places, and their scores in the final test change in a way consistent with the results of their training: Hs. and Wn., who lost consistently in their training, lost here; Hs. owing to conditions of health, and to her extraordinary score in the first test; Wn. to the development of the inadequate method of classification and association which prevented treatment of the stimuli in terms of simple auditory or kinaesthetic imagery. Rt., who, although he showed loss in the latter part of his training yet showed gain in the intermediate part, made a slight gain. Thus the training effect shows itself in this test.

The control reagents whose initial capacity was nearly as high as that of Wn. and Rt. also lost, Dn. losing the greatest amount owing to the development of an indirect kinaesthetic method which was not so trustworthy as his earlier method of basing judgment upon 'affects' or more direct kinaesthetic imagery. The detrimental effect of an indirect method of discrimination has already been pointed out.

(4) *Memory for Visual Symbols*

(a) Processes

In general all reagents were more or less helpless at the beginning of this test because the symbols were strange and evaded fixing. Almost all avoided the pure visual effort for which the test was designed;[135] they compared the symbols

[135] In this respect they conform with the work of Ebert and Meumann's (*op. cit.*, pp. 50, 116) reagents, who declared that the symbols could not be learned from the pure visual impressions. Kuhlmann (On the analysis of the memory consciousness, a study in the mental imagery and memory of meaningless forms. Psych. Rev., 13:342) also found indirect methods of memorizing largely employed: associations, verbal descriptions, motor tendencies of eye and hand. And in another place (Problems in the analysis of memory consciousness. Jr. Philos. Psych. & Sci. Meth. 1907, 4:5-6) he points out a more subtle mode of vicarious functioning; through the more or less extended organic reactions which are evoked by any sensory stimulus,

with conventional characters and things, gave them the names of these associated characters and things, and remembered the names, usually at first without the support of visual imagery necessary to record correctly.

Owing to the inexperience of the control reagents in introspection but little knowledge is at hand of their processes; though that little points to a freer use of visual imagery and visual association of the forms of the symbols, than was true with the trained reagents.

1) Immediate Memory

The process of introspecting after recording from the single presentation of six symbols was difficult, and the processes of perception and reproduction were very imperfectly revealed. There was sufficient evidence, however, to indicate that there was large individual variation.

For the 'note' forms, the effort was a) to visualize the presentation (Hs.), b) to transpose the content into a visual scheme using the musical staff (Wn.), or c) to classify the flags according to spatial relations (Rt.).

For the 'sickle' forms, the effort was generally verbal, to name conventional characters to which the symbols were similar, and to reproduce from kinaesthetic-auditory imagery.

2) Complete Learning

The trained reagents show clearly in their introspections that the processes employed in the 'complete learning' are quite complex and variable.

For the 'note' forms there were three methods of learning employed: a) Naming the number and positions of the flags in the consecutive symbols, for recall in verbal imagery (Hs., Wn., Hhs.); b) classifying the symbols according to the number of flags, and their relations of symmetry, counting the symbols to identify related symbols by number, for recall in mixed imagery largely visual (Rt., Br., Hd.); c) combination

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the lack of prominence of which in consciousness is no criterion of their utility. Bentley's statement that the aids to complete recollection may become the real vehicle of retention, has already been referred to (foot-note, p. 190).

of naming and classifying (Al., Hn.). With methods a) and c) a few symbols at the beginning and the end of the series were usually held in pure visual imagery. The fact that the learning of this series may involve very different kinds of work is illustrated by reagents employing methods a) and b) respectively: a) Hs. learned the series by naming, 1. lower, middle, 2. middle top, 3. one middle, 4. two middle, 5. two bottom; etc. It was a straightforward 'rote' method, converting the presentation into verbal imagery; this was made vivid by verbal repetition, and was recalled through kinaesthetic-auditory imagery, supported by visual memory. Wn. also named but used slightly different terms, adding left and right, and supported her verbal imagery with kinaesthetic imagery of direction in neck and arm. b) Rt. used the early presentations for inspecting the symbols and seeking relations in the position of the flags; then he began counting the symbols as they passed the window and fixing related pairs: No. 7 is No. 1 inverted, 6 is 12 reversed, 9 is 1 with flags at half-mast, etc.; and by drawing the symbol in the air with his pen while cognizing it and repeating the number, he formed associations between pen-movement for reproduction and the number of the symbol; reproduction was supported by visual imagery. This was a more logical method, involving the apperception of relations.

For the 'sickle' forms, the same three kinds of methods were used, and with two exceptions the reagents carried over the methods they had used with the 'note' forms: a) the symbols were named by calling them h, ?, ? inverted, wrong v, right v, y inverted, g, 5, etc., and in reproduction the kinaesthetic-auditory imagery was supported by visual imagery (Hs., Wn.); b) the symbols were classified according to form (Rt.); or c) were learned by classifying some and naming others (Al., Hd.). Hhs. used method a) in his first test and b) in his final; and Hd., who used method b) with the 'note' forms, used method c) here.

In the final test methods usually continued without much change, except on the part of three control reagents: Br. changed

to a more purely visual method, Hn. from more purely visual to naming and visual, and Hd. introduced a method of counting and fixing forms in their positions (the method Rt. used in both tests).

The effect of the interval was to make the test easier for all reagents; this was so marked that a third of them assumed that the series of the final test was identical with that of the first, and felt a strong recognition for some of the sequences. The principal factors contributing to this were: (a) Familiarity with the symbols, b) concrete knowledge of the demands of the test, c) possession of a method, d) in some cases an improvement in method.

(b) Scores

If increase in facility of reproduction of imagery can be shown at all, it must appear in increased scores. In some cases, however, the scores are affected by change in method and are unreliable as measures of reproductivity; and in all cases, presumably, there was some improvement in the application of method leading to more adequate impression of the stimulus, which cannot be separated from the factor of reproductivity in the scores.

1) Immediate Memory

Since the tests in 'immediate memory' were necessarily short, incidental causes of variation, including direction and distribution of attention, must play a correspondingly large rôle. And since it happens that all of the control reagents, except possibly Hn., worked more freely with visual imagery than did the more mature regular reagents, they probably received more benefit from the practice-effect of the test, and this advantage might more than off-set a slight increase in reproductivity brought by the regular reagents from their training.

Individual variation in initial efficiency, for the 'note' forms, ranged from 0 to .329 (1 representing a perfect score), and for the 'sickle' forms, from .080 to .414. Per cent of improvement was reckoned upon the final score and is too irregular to make

the examination of the tables profitable. It ranged, for the 'note' forms, from 25 per cent loss to 100 per cent gain, and the control reagents show the best gains; for the 'sickle' forms, from 0 to 81 per cent; neither group of reagents shows advantage over the other. Several scores are of interest: Wn.'s great improvement in the test on 'note' forms was due to a change of method from the use of the musical staff to naming; Hhs.'s 0 score in his first test was due to inverting each of the two symbols he retained (visually); Rt.'s large improvement on the 'sickle' forms was owing to greater facility in classification. The greatest and most consistent gain on both forms was made by Hd., shown later to be a special case, indicating that training in memorizing 'literal'[136] prose increased efficiency in this test.

2) Complete Learning

The 'complete learning' enabled the reagent to collect himself and work out a method in the course of the first test; and the variation in the factors of attention and adaptation was not so potent a source of error.

Initial efficiency ranged, for the 'note' forms, from 15 to 31.3 presentations, for the 'sickle' forms, from 12.3 to 42.8 presentations. The trained reagents took, in general, fewer presentations than did the control reagents.

Improvement was reckoned in per cent. of initial efficiency:

	Regular			1st Control			2d Control		
'Note' forms	Hs.	(15)	53.3						
	Wn.	(16)	46.3						
				Al.	(19.6)	53.1			
	Rt.	(23)	52.2	Br.	(24)	20.8	*Hd.	(25.6)	45.2
							Hn.	(26.2)	39.9
				Hhs.	(31.3)	42.5			
'Sickle' forms	Hs.	(12.3)	50.4						
				Hhs.	(24)	19.2	*Hd.	(25.2)	64.3
	Wn.	(29.1)	52.9						
	Rt.	(42.8)	50.9						

The number in parenthesis shows initial capacity in number of presentations; reagents are ranged according to initial capacity.

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*Hd. is shown later to be a special case.

[136] In 'literal' prose the learning must be 'word perfect'; which contrasts with 'substance' prose, in which reproduction of ideas is tested.

Since initial capacity of the regular reagents was higher than that of the control reagents, they could scarcely be expected to show as much improvement unless there was a relatively greater increase of capacity in reproduction; the fact that they show greater improvement than four control reagents out of five, therefore, seems good evidence of a definite advantage. Averages indicate this advantage still more clearly:

	Note	Sickle
Trained	50.6%	51.4%
Control	38.8%	

The trained reagents were somewhat more accurate in their reproductions: In the first test two out of six records were without error, as against one out of five by the control group; and in the final test they made four out of six without error, as against three out of six by the control group.

One of the control reagents, Hd., was withdrawn from his group in the consideration of results, because he represents an exception; he had been given a rather severe course of training in 'literal' prose by his fraternity brothers just before the final tests. And although literal memorizing is hard for him, and he left the room after the first test tired out, he found the final test unexpectedly easy, made the two reproductions without error (both scores in the first test were imperfect: .937, .833), and reduced presentations 45.2% and 64.3%. There is no doubt about the influence of his prose training upon this test.

A negative 'spread of training' seems to be indicated by Rt.'s results in the first test in 'complete learning.' His method was that of classification and grouping, and introspections show that his habit of disregarding the stem in the 'note' forms, which was invariable, was carried over to the 'sickle' forms, where both stem and curve were variable, and caused confusion; he learned the 'note' forms in 23 presentations, while it took 42.8 presentations to learn the 'sickle' forms. Not all of this difference, however, should be attributed to negative spread of training, for the 'sickle' forms are more difficult to classify and group than are the 'note' forms.[137]

[137] Though not necessarily more difficult to learn by naming, as is shown by the initial capacities of Hs.

(c) Summary

The process of memorizing visual symbols did not engage much visual imagery; the usual method was to associate the symbol with some familiar thing and remember it by verbal-motor imagery of the name of that thing, or to classify the symbols for reproduction from logical memory. Visual perception served principally to analyze and interpret the symbol for conversion into verbal-motor terms or to effect classification. Where visual imagery was used, it supported the more prominent kinaesthetic-auditory. The complete process utilized a combination of verbal-motor, kinaesthetic, visual, and auditory imagery.

The scores of the 'complete learning' show that although the control reagents began with less efficiency and therefore might be expected to make greater gain than the trained reagents, the latter, and one of the control reagents who had training in memorizing literal prose, made more improvement. The only explanation at hand is that training in retaining and recalling imagery occasioned by intensities of sound contributed to facility in retaining and recalling the combined imagery used in this test.

e. Conclusion

The results of this experiment supplement those of the Experiment on Attention in illustrating the variability in processes engaged upon a simple task and in locating the variability in each of the successive 'moments' of a test.

Although the training, with its evident retention and reproduction of auditory and other imagery, did not result in improvement in sound discrimination, analysis of processes used in the training shows change in those processes, and training-effect shows itself in the tests.

In Test 1. (Recognition or Choice of One of Two Letters) the regular reagents increased R cases in 'uncertain' choices due to more 'maturing' of 'fringe' imagery of the last presentation and to strengthening this process by uniting to it the influence of preceding identical letters.

In Test 2. (Reproduction and Recognition of Letters) the

anomalous results emphasize the worthlessness of purely quantitative treatment of the results of 'mental tests.'

In Test 3. (Sound Discrimination) the results of the regular reagents are consistent with those of their training on similar material; but habituation to the 'metalic' sounds in the training caused interference with the transference of practice-effect in the early series with the 'wooden' sounds of the test. The greatest loss, by a control reagent, illustrates the detrimental effect of an indirect method of discrimination, thus agreeing with the training results of Wn.

In Test 4. (Memory of Visual Symbols) the trained reagents show their advantage, in 'complete learning,' over the control reagents, except in the case of Hd. whose large and consistent gains in both 'immediate memory' and 'complete learning' indicate clearly that his inter-test training in memorizing literal prose contributed to his facility in memorizing these symbols.

One of the corroborating facts in the results is that the regular reagent (Wn.) who avoided using simple imagery in her training showed less gain in Test 1. and a loss in Tests 2. and 3., where simple imagery was requisite, but was not handicapped in the 'complete learning' of Test 4., where the imagery could be more complex.

It is noteworthy that all the gross quantitative results of Tests 1, 2, 3, and of 'immediate memory' in Test 4, were worthless; only by careful analysis of scores and introspections was the fact of 'spread of training' made evident at all.

The chief contribution of the experiment is: That the specific training did not result in gain in efficiency with the training material, but that it did result in changes in the processes it engaged and it showed its 'general' character in influencing the processes involved in Recognition or Choice of One of Two Letters (Test 1) and in 'Complete Learning' of visual symbols (Test 4) both of which differed radically from the training in sense-mode of impressions and in methods of work.

Facts of this character, already noticed, in the Experiment on Attention, in the failure of Al. to improve after his third day of training (p. 93), and in the failure of Rt. and Sl. in their

effort to apply the method of learning developed in their training to commercial signs (p. 154), indicate that not only is there general effect of special practice, both negative and positive, but there is an occasional negative special effect of special practice: Changes in the mental processes incidental (1) to the greater complexity of the processes involved in the next step of progress, (2) to the conscious application of a method already automatic, (3) to the development of a method which neglects the essential process, (4) to change of attitude toward the experiment, or (5) to chance variation in the processes, may cause retrogression in efficiency, indicated by a drop in the practice-curve. It is well known that in continuous practice the scores on the immediately following days suffer from this retrogression. Retrogressive effect of special practice must therefore be taken into account in testing for general effect. This negative special effect shows itself in negative general effect in tests similar to the training, and is not inconsistent with positive general effect in tests less similar to the training.[138]

3. Critique of the Test-Training-Test Type of Experiment

Much has already been said by way of a critique upon the Test-Training-Test type of experiment in the introduction to The Experiment on Attention (pp. 65-70) and under the headings of Extent and Variability (pp. 167ff) and The Practice Curve (pp. 173ff), in the same experiment, as well as throughout the text in the discussion of The Test Results; but it seems desirable to bring the critique together into a plain statement unencumbered with the concrete evidences upon which it is based, and to illustrate with a clear hypothetical case.

The prime requisites of this type of experiment are (1) that the tests shall afford a reliable measurement of a known process or group of processes, (2) that the training-effect shall not only be measurable but shall be capable of definite description in terms of changes in processes, and (3) that change in efficiency in the

[138] In this respect it resembles 'interference,' which, however, is more transient.

final test shall be described with sufficient precision to indicate its dependence upon, or independence of, the training-effect. Only when these requirements are met can the functional relationship of mental processes of various kinds be determined with certainty.

In order that the processes tested can be known, trustworthy introspection is essential. If it is dispensed with, or if it is faulty, the test-averages may not belong to the same denomination, in which case they can be neither grouped nor compared for any intelligible purpose.

Suppose that the capacity of the reagents K., L., M., N., and P. to progress from station A. to station B. is measured by a test; that K. and L. are trained in progressing from R. to S.; and all are again given the test from A. to B., for the purpose of determining the training-effect upon the capacity of K. and L. Suppose progression in this illustration is made by travel, and in the first test K., N., and P. walk, and L. and M. ride bicycles; in the training K. and L. both walk; and in the final test K. and P. walk, L. and M. ride bicycles, and N. takes an automobile. Let the following table show the results, in minutes:

			Regular		Control		
			K.	L.	M.	N.	P.
Training	Beginning		125	130			
	End		95	100			
Tests		First	125	20	25	135	125
		Final	100	22	20	9	120
	Difference		—25	+2	—5	—126	—5
	Average		—11.5		—45		

Conclusion: Results show that training in progression from R to S. has a negative influence upon capacity to progress from A. to B., since the practice-effect of the first test upon the final (-45) greatly exceeded the gain (-11.5) made by the trained men.

Analysis of processes, however, shows that training-effect was transferred by K.; he used the same processes, as affected by practice, in the final that he did in his first test and in his train-

ing. A negative effect is shown by L., since his practice in walking caused his bicycling muscles to retrograde. The anomalous gain of N. is the result of a radical change in processes, independent of the purpose of the test. For accurate knowledge of the reliability of the test-results other conditions affecting the progress should be known: whether the traveler had to turn out of the road into rough footing to pass vehicles, whether any part of the road was slippery, owing to the sprinkling cart or rains, whether any unusual conditions affected the work. In other words, the conditions must be under the control of the experimenter or must be known in order to be reckoned with; and in mental tests these conditions are both objective and subjective.

This illustration represents the facts all too accurately for the comfort of those of us who have employed this type of experiment, and have struggled with anomalous results. Merely quantitative treatment is worthless. Incidentally, it is difficult to see how any method of statistical correlation can improve upon the simple treatment shown above; and it is equally difficult to imagine a value for even the single test averages: *e.g.*, what can we know by finding that the average initial efficiency in progressing from A. to B. is 86 minutes, when no single ability or group of abilities approached that measurement?

It seems patent that results from great numbers of reagents cannot be more reliable, when different kinds of work are measured; this sort of error will not cancel itself out by multiplying it, nor will the 'probable error' have any meaning as an indication of the reliability of the measurement.

Practically, the requisite for introspective description of processes limits the number of reagents. The security of greater numbers may be obtained by repetition of the whole experiment.

The requirement that the test shall afford a reliable measurement is not easily met, for the reason that it must be arbitrarily decided as to how much practice-effect to include. The usual preliminary series which gives an opportunity for adaptation to the work of the test does not remove the difficulty; practice-

effect continues and at various rates with different reagents,[139] especially if different methods of work are employed. In almost any case a single test score is bound to be unreliable; in some of our tests in the Experiment on Attention averages of five series,

[139] Otis and Davidson (The reliability of standard scores in adding ability. Ele. School Teacher, 1912, 13:91-105) found different types of learning ability among 202 8th-grade children who were given 25 tests in adding; amount of improvement, moreover, bore no constant relation to initial efficiency. Wells (The relation of practice to individual differences. Am. Jr. Psych., 1912, 23:75-88) who trained 10 adult subjects 30 days on adding and marking out zeros, concluded that "A superior performance at the beginning of special practice is not necessarily, nor even probably, attained at the sacrifice of prospects for further improvement. A high initial efficiency may carry with it as much or more prospect of improvement under special practice than a low one. . . . Not practice, but practiceability, is responsible for the superior position of such an individual" (p. 88); if the individual's high efficiency is the result of greater practice, his position may be near the "physiological limit" or end of his practice-curve, and practice-effect may be expected to be small; if it is the product of greater ability (native endowment), his position is nearer the beginning of his practice-curve and practice-effect may be expected to be large (p. 75).

That the reagent with the higher initial ability improves more in practice was found in tests in tapping by Bolton (Relation of motor power to intelligence. Am. Jr. Psych., 1903, 14:621), in discriminative reaction on a typewriter by Culler (Interference and adaptability. Archives of Psych., 1912, 3: No. 24, p. 57), in marking out zeros by Wells (*op. cit.* p. 79ff), in adding by Wells (*op. cit.*) and Hahn and Thorndike (Some results of practice in addition under school conditions. Jr. Ed. Psych., 1914, 5:79), and in multiplication by Thorndike (Effect of practice in a case of a purely intellectual function. Am. Jr. Psych., 1908, 19:374ff).

That the reagent with the lower initial ability improves more in practice was found in training in learning non-sense syllables by Müller und Schumann (Experimentelle Beiträge zur Untersuchung des Gedächtnisses. Zeits. f. Psych., 1894, 6:328) and von Sybel (Ueber das Zusammenwirken verschiedener Sinnesgebiete bei Gedächtnisleistungen. Zeits. f. Psych., 1909, 53:356), in marking out letters by Binet (Attention et Adaptation. Année Psych., 1899, 6:368), in free associations by Wells (Practice effect in free associations. Am. Jr. Psych., 1911, 22:2-3), and in adding by Thorndike (Practice in the case of addition. Am. Jr. Psych., 1910, 21:485).

Hollingworth (Individual differences before, during, and after practice. Psych. Rev., 1914. 21:1-8), who followed Whitley and Wells in attacking the problem directly, gave 175 repetitions of seven tests to 13 adult reagents, and calculated the coëfficients of correlation between the orders of abilities in the 1st, 5th, 25th, 50th, 80th and 130th trials and the last trial. The averages

taken on two days, were unreliable. The averages used in our Experiment on Sensible Discrimination were much more reliable, and they involved the work of three days, about forty-five minutes each. In reaction, discrimination, and tachistoscopic tests it should probably extend to at least 100 experiments.

The number of tests should also be limited on account of inter-test practice-effect, although this source of error may be partly eliminated by arranging the series composing the tests in 'double fatigue order';[140] successive tests may be made equivalent in difficulty by using Müller's 'cyclical changes' ("Zyklischen Wechsels").[141]

The training should perhaps be longer than is usual, and as rigorous as circumstances will permit, say six months for such work as cannot be trained to maximal efficiency in less time.

The control reagents should equal the trained reagents in

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of these coëfficients were .41, .61, .73, .77, .85, and .92, indicating a gradual approximation, through these various levels of practice, to the final order, and, consequently, the insecurity of the results of the early levels as indicative of the final relative capacities of the individuals tested. In adding and in cancellation of digits the coëfficient of $r = +.75$ was not reached until the 25th trial; in tapping, the 130th trial; but in naming colors and in coördination (aiming) it was reached by the 5th trial.

An indication of change in processes during practice, which had the effect of diminishing individual differences, is to be found in the coëfficients of correlation between tests at varying stages of practice published by Winch (Jr. of Philos. Psych. and Sci. Methods, 1911, 8: 377) and Hollingworth (Correlation of abilities as affected by practice. Jr. Ed. Psych., 1913, 4: 405ff); Hollingworth found the coëfficients (averaged for his seven tests with 13 observers) for the 1st, 5th, 25th, 80th, and 205th trials to be .065, .280, .320, .390, and .490, respectively.

That differences in rate or amount of improvement in practice may be dependent upon differences in mental processes is shown by McMein and Washburn (Effect of mental type on the interference of motor habits. Am. Jr. Psych., 1909, 20: 282ff) who found that reagents who used visual imagery freely made more rapid improvement in card-sorting, and overcame interference, produced by turning the compartment-scheme through 180°, more easily, than the other reagents. And von Sybel (Zeits. f. Psych., 53: 356) found that the practice-effect was greater for reagents with the less initial facility in method of learning.

[140] As was done by Fracker: *op. cit.* p. 63.

[141] *Vid.* Müller: Zeits. f. Psych., 1905, 39: 116.

number, in initial efficiency, and in facility in introspection, or their results may not be comparable with those of the trained reagents. If these conditions are met, comparison, both qualitative and quantitative, may be intelligently made; and the simplest mathematical treatment would seem the least objectionable, even the per cent form of expression being serviceable.[142]

Finally, two more criticisms with reference to the interpretation of difference-scores, are important: (1) An exceptionally large difference-score is a symptom of radical change in kind of work and calls for individual treatment; (2) A small difference-score does not necessarily mean that training-effect is absent; it may merely be the resultant of positive and negative factors in that effect. In either case introspective description of processes must, when possible, furnish the chief grounds for interpretation.

4. Analysis of the 'Common Factor'

It is generally agreed that 'the Common Factor' is responsible for the general effect of special practice; but as to what it is or may be, there is difference of opinion. It is interesting to note that its nature is growing more complex as experiment and discussion advance. In the early days it was regarded as largely physiological and related simply and immediately to the data of presentation, or, as mental habit, related definitely to the method of the experiment; in marking out words, for example, it was said to consist principally in eye-movement, pen-manipulation, and in the habit of looking for the least common letter. And

[142] The chief objection to the per cent form of expression involves the presumption of a direct comparison of measurements of improvement made by reagents who differ widely in initial efficiency, (*vid.* Whitley's hypothetical case showing how varying methods of portraying practice-effect lead to varying conclusions, *op. cit.* 100-105) or who differ widely in their positions with reference to the end of their practice-curves (Wells: Am. Jr. Psych., 23:82-85). This objection appears to be removed if, upon the grounds of qualitative difference in work, capacities differing widely in initial status are declared to be not directly comparable, and if, upon grounds of individual variation in the form of practice-curves or of multiple types of practice-curves, the individual's position on the practice-curve cannot be determined and, consequently, no remedy is apparent.

'general effect' was said to decrease directly with decrease in similarity of matter and method between the two tests.[143]

More recently, the 'Common Factor' has been found to be made up of subjective factors, not altogether, but largely, independent of the matter and method of the tests (admirably shown by individual variation), and to be anything but simple, although the illustrations used in discussion are still apt to give it the appearance of a simplicity and definiteness which the authors do not really intend.[144]

If one set of processes consists of elements a,b,c,d,e, and another of e,f,g,h,i, training in the one is said to improve the other through the common factor e; the effect is greater in case the latter set should consist of c,d,e,f,g. Fracker[145] has suggested the term 'Transference' for this kind of influence, but he provides for another kind of 'general effect' which he calls 'Spread of Training,' which is found when the second set of processes consists of f,g,h,i,j, none of the elements of which is common with any of the first set but some of which are 'consciously' or 'subconsciously' connected with some of the latter in the mind of the reagent.[146] And Sleight[147] claims that to be effective the 'common factor' need not be recognized by the reagent as common; and that it may not be effective at all because it is so firmly bound up with its associates that it cannot be lifted out and used where its associates are not also common.

[143] *Vid.* Thorndike and Woodworth, 1901, *op. cit.*

[144] *Vid.* Fracker, 1908, *op. cit.* Sleight, 1911, *op. cit.*

[145] Fracker, *op. cit.* 85.

[146] The writer believes that Fracker has performed a real service in pointing out those distinctions and in offering apt technical terms for them; and he has adopted the terms in the preceding pages, but has thought best to characterize them in a different way, suggested by the two widely different classes of elements that contribute to improvement in training: The sudden rise of the curve in the beginning stages is due largely to 'adaptive' changes in which elements of former experience have been 'transferred' bodily to the new work; the later, more gradual, rise, broken by plateaus, is due to a more orderly development which was called "practice effect proper." The influence of this practice-effect, apart from transference, was termed "spread of training (see p. 230).

[147] Sleight, *op. cit.* pp. 440f.

To locate and define the 'common factor,' a thorough analysis of a set of processes into its elements is necessary; and this is exceedingly difficult because introspections, even when expertly made, are scarcely ever complete descriptions and reveal only the elements selected from the content of consciousness which enjoy a considerable degree of clearness. No doubt this incompleteness tends to a portrayal of the elements as discrete units connected in simple mechanical relations somewhat congruent with the old associational psychology. Admittedly incomplete analysis, however, yet shows, when it is at its best, that the elements found are not of the same order and are not simply related.

a. *Factors involved in one experiment*

The difficulty of defining the common factor and of stating the laws under which it operates, may be best apprehended, perhaps, by following a single experiment through its three or more parts in an effort to locate some of the elements of the processes which may serve as the 'Common Factor':

(1) The first period, between the 'ready' signal and the appearance of the stimulus, is characterized by a set of consciousness which includes certain predispositions or tendencies which affect the course of the processes to follow. It includes an emotional attitude toward the experiment and a corresponding 'will to succeed'; definite ideals of efficiency to be attained; ideas of method to be used. This 'anlage' comes to every experiment as an adaptation to a more or less novel situation, and is generalized therefore from past experience, is modified in recurring experiments on the basis of the resultant experiences from the foregoing; and engages at once the selective function of attention in the adaptation, and the function of control in carrying out the initial steps of the purpose, such as the readiness for a certain direction and distribution of the attention, and renewal of definite imagery which is to be used in ready recognition or reception of the material.

(2) The period of dealing with the stimulus may be either short or long. (a) If short, as in simple reaction, sensible dis-

crimination, or tachistoscopic work, quickness of adaptation or alertness of the attention, as well as degree of concentration, is a condition of good performance, since it affects directly sensitivity for the stimulus. The direction and distribution of the attention prepared for are carried out; part-processes are coördinated, external and internal distractions are inhibited, unessential imagery is reduced to a minimum. (b) If long, as in repeated reactions (card-sorting, typewriter-reaction, marking out *a's*), or in memorizing, there are in addition to the foregoing, sustained attention, more complicated part-processes, greater use of categories of classification, more development of method in process, more use of individual forms of imagery. In any case the process varies more with the form (in reaction, or memorizing) than with the material of the experiment.

(3) In tachistoscopic or memory work the period between the stimulus and recording may be used chiefly to make imagery definite for recording and may also serve for 'maturing' content into the field of clearness. In sensible discrimination it may serve for comparison of images. The control of the attention is therefore important, else the vague imagery will not be so directly entertained, and distraction will cause a loss of some of the clear imagery. Coördination of retaining and defining processes is demanded.

(4) In the period of recording, coördination of the retentive and reproductive processes call for economic distribution of the attention.

A single experiment thus contains many factors of a formal nature which cannot be treated as coördinate elements.[148]

b. *Practice-effect upon these factors*

Analyses of processes in training and tests in the preceding experiments show in what way these factors are changed through training:

(1) The attitude becomes optimal in tone, the 'will to suc-

[148] And consequently cannot be illustrated by a, b, c, d, e, f, etc., as though simply and mechanically related either with each other or with 'content' elements.

ceed' is firmer, the essential processes can be more definitely prepared for in the set of attention, strong expectation of particular content drops away.

(2) (a) Where the period of dealing with the stimulus is short, as in reaction and sensible discrimination, intensity and direction of attention comes under better control, resulting in greater sensitivity for the stimulus, greater preparedness for reaction, or higher discriminability, and closer coördination of sensation and movement or of discrimination and report. Adventitious imagery drops away. (b) Where the period is long and the processes are successive and complex, as in reaction with discrimination and choice (card-sorting, typewriter-reaction) there is first an elaboration of method involving analysis and classification of the stimuli and synthesis of like stimuli and similar relations into a scheme which mediates between stimulus and reaction. Improvement here consists in adaptability in forming an adequate scheme, and in an economic distribution of the attention to the various part-processes it involves. Then comes the dropping away of retarding factors, the stimulus becomes coördinated with its reaction, and improvement here consists in sustained attention and in a distribution of attention which equalizes readiness for all reactions; kinaesthetic accompaniments of recognition (as pronouncing, or movement of some part of the body) and of initiating the reaction, and those grosser bodily movements, tensions, and strains, accompanying effort, drop away.

In memorizing cards of exposed letters, figures, or symbols, methods of analyzing, classifying, and grouping, and of coördinating part-processes involving disparate imagery and different grades of clearness, grow up; systems of representative imagery (associations) develop; complexity of content increases from a two-fold to a four-fold system of imagery, and from a two-level to an eight-level grade of clearness.

Improvement in this part of the experiment involves factors which are common to all processes of learning, and also factors which are specific to the material or the form of the experiment. But the relative importance of these two classes of factors may

be illustrated from reaction with discrimination and choice. In no exercise, probably, are the special factors more important. The process of forming coördinations between specific stimuli and specific reactions is the end attained by the training. Yet those specific coördinations constitute the least part of the training effect; power of forming coördinations between other specific stimuli and other specific reactions has been so much increased that learning new systems is greatly facilitated.[149] Memorizing furnishes another illustration: Methods of apperceiving and representing the material are more permanent than the material learned, and have a wider application.[150]

(3) In the period of fixing the imagery and of 'maturing' vague imagery into impressions definite enough for cognition, improvement consists in a peculiarly delicate control of attention in respect to direction, to distribution, and to degree; and this experience once realized probably makes it possible to entertain any kind of imagery in the same way. (It resembles in nature the hearing out of an 'upper partial' from the complex clang of a vibrating string, in that stimulation directs the attention; but it is not so simple a process.) Improvement through training has the effect of increasing sensitivity to central excitations, of increasing both the liability and the fidelity of reproduction.

(4) Improvement in coördinating the retaining, reproductive, and recording processes effects an economic distribution of attention which results in a singular self-possession and poise, a satisfying feeling of fitness for the task. Economic distribution of the attention to such complex processes is a matter more of form than of content, for both stimuli and form of expression may change yet that complicated formal process is to some extent available.[151]

This statement has necessarily been made in general terms and has emphasized the more formal elements which are fitted to fill the office of the 'Common Factor.' The more concrete, and

[149] *Vid.* Bair, (*op. cit.*) and Liddle (*op. cit.*).

[150] *Cf.* Fracker (*op. cit.* 91), and Gamble (*op. cit.* 97, 149).

[151] *Cf.* Fracker (*op. cit.* 95).

presumably more specific elements, dependent upon the particular work of the task, have been abundantly illustrated in the discussions of test and training results. The more formal elements appear at this juncture to need emphasis since they are so likely to be overlooked, especially when the analysis is expected to lead to simple elements mechanically related.

c. *'Spread of Training'*

When the more orderly changes in processes effected by practice in one task are carried over to another we have what the writer thinks is best described as a *'Spread of Training.'* This occurred more conspicuously in the Experiment on Marking out Words, the Experiment on Sensible Discrimination, and the Experiment on Reproduction. The 'Common Factor' appears to be *formal* and to be relatively detached from the data of presentation, and, in the last experiment, from method. No systems of imagery were carried over. The practice-effect consisted in stripping the essential process of unessential factors, in facility in developing automatic coördinations, in establishing habits of higher order, in dealing more effectively with vague imagery, etc. This kind of general effect seems to rest more directly upon *modes of mental processes* than upon the material of experience, and seems capable of description largely in terms of emotional and volitional attitudes and of the control of attention.

d. *'Transference'*

The term *'Transference'* seems particularly applicable to the carrying over, from one task to another, of the *material of experience.* It takes place typically in the 'adaptation' to a novel exercise, and in the application of physiological processes and systems of imagery in an exercise similar to the exercise in which they were developed.

These two kinds of general effect of special practice bear to each other a relation analogous to form and matter in logic, and, although inseparable, should be discriminated for the purpose of prohibiting the limit of search for the 'Common Factor' to the case of 'Transference' alone. Enumeration of the elements of

the material of experience will then not exhaust the processes in an exercise, to be considered for the purpose of locating the 'Common Factor.' In preceding pages when the causes of general effect of practice have been discussed, in the review of the results of experimentation conducted by others,[152] and by ourselves,[153] some elements properly falling under the head of 'Spread of Training' were always included in the consideration. If the reader should glance over the 'Summary' (pp. 31ff) of the evidence for relationship between mental processes, from the literature, he will note that the eighteen numbered cases all involve 'Spread of Training,' all but eight involve it almost exclusively, and only two involve a large share of 'Transference.'

e. *Both kinds of General Effect selected from former experience*

It has already been pointed out[154] that elements of former experience contribute to the work of a test. This is applicable to both kinds of general effect, as may be seen by inspecting the analyses of processes in the last two experiments.

To illustrate, with reference to *'Spread of Training,'* the reagent comes to the experiment with emotional factors, volitional attitudes, and modes of mental processes already established: His work in tachistoscopic tests and in learning 12-letter-rectangles is influenced by favorite letters, preference given to right or left position, distribution of attention, *etc.*, in discrimination tests, by concern for an equitable distribution of 'greater' and 'less' judgments and by other factors leading to constant errors;[155] he gives preference to imagery of one particular sense-mode, as is illustrated by his representative imagery in tests in discrimination, and in memorizing, although he may vary this mode upon occasion, for varying content or method;[156] he comes to tests in learning 12-letter-rectangles, and in memor-

[152] Pp. 19, 22f, 23f, 27.

[153] Pp. 36ff, 41ff, 46ff, 61ff, 173, 217ff.

[154] Pp. 173, 180f.

[155] *Cf.* F. Angell's Review of "Zur Analyze der Unterschiedsempfindlichkeit" von Martin u. Müller, in Am. Jr. Psych., 1900, 11: 266-7.

[156] *Cf.* Segal, J: Ueber den Reproductionstypus und das Reproduzieren von vorstellungen. Arch. f.d. ges. Psychol., 1908, 12: 124-236.

izing, with tendencies designed to facilitate a particular method of coördinating imagery of different modes, and of placing reliance mainly upon methods of rote learning or of classification and grouping, and to tests in compound reaction and in memorizing visual symbols with principles of classification; *etc.*

To illustrate with reference to '*Transference*,' the reagent applies elements of the material of former experience, especially in the forms of particular imagery and systems of imagery. To the former belong the conventional things by which visual symbols are cognized and named for memorizing; groups of letters from common phrases and names, cattle-brands, wheat-sack initials, names from Biblical and classical literature, *etc.* used in learning 12-letter-rectangles; the various representative visual and kinaesthetic imagery in discrimination of sound, as of flashing light, falling bodies, or raising the toes for louder sound; *etc.* To the latter belong the musical staff for memorizing 'note' forms, map directions for cognizing symbols with radii variously turned, series of steps for memorizing sound intensities, mathematical relations for grouping numerals, logical schemes for classification of stimuli in compound reaction; *etc.*

This application of the elements of former experience is familiar to every one who has considered at all critically the process of learning. But it should perhaps be pointed out that in the application the former elements are not merely picked up as stable units and mechanically inserted in a new process. The elements come with a certain mutation determined by the novelty of the situation, and their application involves a degree of invention. The elements of consciousness do not appear to behave in the manner of reflex-action, and it does not seem possible to get a purely 'specific' effect of practice when the practice is a conscious process. All elements may be the 'Common Factor'; all effects of conscious practice are to some extent 'general effects.'

f. *Provisional classification of Common Factors*

In view of the complexity of the situation it is hazardous to attempt a complete classification of the 'Common Factors,' yet the writer feels inclined to offer the following provisional list:

Common Factors

I. Objective.
  1. Likeness of material.
  2. Likeness of form.

II. Subjective.

A. Form of Experience.

  1. Aufgabe (interpretation of instructions).
  2. Attitude (emotional, volitional).
  3. Ideals (controlling concepts).
  4. Purpose (definition of volitional attitude).
  5. Intellectual processes.
     a. Elaboration of method.
     b. Short-circuiting of processes.
     c. Higher order of control.
     d. Elimination of accompaniments of
        (1) Discrimination,
        (2) Cognition,
        (3) Movement,
        (4) Reproduction.
     e. Growth in simplicity or complexity of imagery.
     f. Coördination of part-processes.
  6. Control of attention.
     a. In degree,
     b. In direction,
     c. In distribution,
     d. In quickness of adaptation,
     e. In duration of concentration.

B. Material of Experience.

  1. Simple imagery (Visual, auditory, kinaesthetic, tactual, *etc.*) .
     a. Direct.
     b. Associative.
        (1) In the same sense-mode.
        (2) In different sense-mode.
  2. Compound imagery (Of the above).
     a. Direct.
     b. Associative.
  3. Complex imagery. (Spatial, temporal, causal, histrionic).
     a. Direct.
     b. Associative.
  4. Systems of Imagery (Representative schemes, mnemonic devices).

III. CONCLUSION

1. Evidence from the literature of experimental psychology indicates a functional relationship between various mental processes. This relationship is sometimes positive, sometimes negative. Specially designed experiments show that 'specific' practice is never wholly 'general' in its effects; is often largely 'general,' and is probably always somewhat 'general.' Under the experimental conditions, the 'general' effect usually ranged, in amount, from one-fourth to three-fourths of the gain made in the specific practice (*vid.* Summary, pp. 31ff).[2]

2. Results of the repeated experiments of (a) Marking Out Words, and (b) Estimating Weights, support the evidence for 'general' effect of 'specific' practice, and indicate through introspective analysis, what change in the practice is responsible for the 'general' effect.

a. The training on Marking out Words, on printed pages, containing both letters *e* and *s*, increased efficiency by reducing the recognition of words as containing *e* and *s* to its essential process, through relieving it of unnecessary and retarding accompaniments, chiefly kinaesthetic, motor, and auditory. This factor in the training-effect was responsible for the marked increase in efficiency shown in the tests on marking out words containing other pairs of letters, on printed pages and on manuscript sheets. Some 'specific' effects of practice (such as word-reaction) which would not contribute to 'general' effect, or, if so, only in a negative form, were also found; but the principal factor of improvement in the practice was the main factor of improvement in the tests,—a general effect (34-39).

b. The training on Estimating Weights resulted in building

[1] The statements under this head will be found in more amplified form in the Conclusions of the various experiments, which may be located by reference to the Table of Contents.

[2] The page numbers in parenthesis refer to material upon which the statements are based, including conclusions to experiments.

up a definite idea of the field represented by the training weights (40-120 grams), or in deepening impressions of the weights at the upper and lower limits of this field; and these ideas of value improved the capacity for estimating weights differing in kind, both within the field of training and above it. Both reagents showed more improvement in tests on objects dissimilar to the training-weights, but within the field, than they made in training; and one reagent made his greatest gain in the test on objects above the field. These anomalous results, together with the introspective evidence of the complexity of the estimating process, suggest that simpler processes should be chosen for measuring and analyzing 'general' practice-effect (pp. 39-42).

3. The two experiments, (a) Sensible Discrimination, and (b) Reaction with Discrimination and Choice, designed to determine whether there is 'general' effect of 'special' practice when the processes involved are as simple as possible, and when the tests differ from the training (a) in sense-mode of reception of the stimuli, or (b) in the form of the stimuli and their motor-response, but when the tests and training involved the same kind of mental activity, contribute results indicative of the real complexity of the relatively simple processes, and of the 'general' nature of practice-effect.

a. Training in Sensible Discrimination of intensities of Sound resulted in improvement in efficiency through divesting the discriminating-process of its unessential and complicating factors consisting in irrelevant or fantastic imagery, indirect sets of attention, vascillating attention, expectation, *etc.,* all of which render judgment illusionable, and this improvement was transferred to the tests in sensible discrimination of shades of gray (pp. 42-50).

b. The training in sorting cards bearing distinctive colors into a cabinet with six compartments increased efficiency in Reaction with Discrimination and Choice, which was transferred to reaction to letters on a typewriter, (a) noticeably in regularity with two reagents for whom the latter had become automatic before the training in card-sorting was begun, and (b) markedly in speed

with two reagents for whom the latter was in course of practice. The practice-effect responsible for the improvement in the card-sorting and for the improvement transferred to the typewriter-reaction was (1) the habit of stripping the essential process of its adventitious accessories, consisting chiefly in (a) kinaesthetic and verbal elements accompanying and retarding the recognition of the stimulus, (b) mnemonic schemes which served the purpose of building up coördinations between stimulus and reaction, (c) false motions, and (d) bodily strain, and (2) such control of the attention (a) that the various possible reactions were about equally prepared for and (b) that the series of continuous reactions were not so frequently broken by balks due to distraction (pp. 50-64).

4. Disagreement in the results of investigations as to the extent of the general effect of special practice, in hypotheses proposed for the causes of the transference of practice-effect, and the frequency of cases of an anomalous character which defy any consistent hypothesis, are probably due to differences in technical procedure in experimentation, to differences in kind and length of training and in the relation of training to tests, and to differences in statistical treatment of results. They call for more qualitative investigation to the end of determining more precisely how training affects the processes engaged in the training, how training-effect affects the test-capacities, and how training-effect, both direct and 'general,' may be properly expressed in quantitative terms. A study of anomalous cases suggests the importance of determining (a) the extent of variability in processes, both with a single reagent and between different reagents who set themselves to the same objective task, (b) the causes of this variability, and (c) its effect upon the scores (pp. 64-69).

5. The Experiment on Attention, which provided a qualitative study of the kind, extent, and causes of variability in processes engaged by a single reagent in a single test and in a range of tests, and of variability between processes engaged by different reagents in identical tests, yielded results which show:

a. That it is the rule for the individual reagent to vary his processes while at work on a single test and often to change

radically, in the final test, the methods of work employed in the first.

b. That the causes of this variability, beyond general conditions of health, interest, *etc.,* and incidental occurrences, such as winking at the moment of the presentation of the stimuli, and accidents in manipulation of a key, *etc.,* were of a fairly specific nature varying in accordance with the nature of the work of the test, such as voluntary or undesigned shifts of the attention to various elements of the processes engaged, changes in the extent of the distribution of the attention over part-processes and their coördination, the constructing of more adequate methods, and the practice-effect of dropping out of the process unessential factors, in heightening sensitivity, discrimination, reproduction, habituation to distraction, and in building up habits of higher order.

c. That in almost every test individual reagents differ from each other, often greatly, in the way in which they performed the work of the test.

d. That they differ in the 'aufgabe,' or their understanding of the instructions for the test, in their general experience from which elements are selected, by way of adaptation, to begin work, in the order and degree of the changes in processes due to the variability in the single reagent's work noticed in (b) above (pp. 64-184, particularly 167-173).

6. The training results of this experiment brought into clear relief the fact that practice-effect itself involves changes in processes: At the beginning of training on Test 17, only letters that had been clearly seen were recorded; at the end, letters were correctly recorded that had not been "seen," but that 'matured' from the 'fringe' content of consciousness; the conquest of the 'fringe' content was a practice-effect that extended the area of distinct perception whilst increasing efficiency on its own account. At the beginning of training on Test 13, only letters the visual impression of which was converted into kinaesthetic-auditory (verbal) imagery were recorded; at the end, letters were recorded from four distinct kinds of imagery; at the beginning, the process was a simple 'rote' process; at the end, it was a complex process

involving coördination of many part-processes. The conception that repetition in the learning-process increases efficiency similarly to repetition of a skilled movement in fixing a habit is an absurdity against which the fact of the increasing keenness of consciousness accompanying the progress of the former ought to have been sufficient warning. Repetition in learning changes the process (pp. 173-176).

7. Altho the series of tests proved inadequate as a measure of attention, there was some quantitative indication of a practice-effect upon certain forms of attention (or attentive forms of consciousness) that were of general application: (1) The control of attention to seize the stimuli of the moment; (2) equitable distribution of the attenion over the various part-processes, leading to coördination of disparate imagery, of processes of retention and reproduction, or of imagery and movement; (3) sustained application, involving inhibition to external and internal distraction; (4) an intensity of application, effective in lowering thresholds of sensation and reproduction, and in fusing coordinations (pp. 178-180).

8. There was ample introspective evidence for general effect of special practice, both negative and positive. Not only were methods of work, forms of processes, and systems of imagery, transferred from one kind of work to another, but in the adaptation to the novel work of the tests elements of former experience were selected and applied, which when acquired must always have been 'specific' and as applied are always 'general' (pp. 180-181).

9. The Experiment on Reproduction supplemented the preceding experiment in illustrating the great variability in processes engaged in a single test, locating the variability in each successive 'moment' of the single test, and in offering new evidence, both quantitative and qualitative, for the positive and negative general effect of special practice, when the tests and training differed so greatly in both material and method as to exclude a 'transference' of the elements of experience (184-219).

10. The training on discrimination of sound did not result in improvement in efficiency with the training material. But, ac-

cording to introspective evidence, it effected changes in the processes employed. Quantitative analysis showed that the practice-effect of the evident exercise of retention and reproduction of auditory and other imagery 'spread' to the tachistoscopic test of Recognition or Choice of One of Two Letters, and to the test on the Complete Learning of series of visual symbols, both of which involved retention and reproduction of imagery (pp. 184-219). Retrogression in efficiency in the course of practice, and failure to apply methods developed in training to material slightly different, *etc.*, indicate a negative special effect of special practice, which should be taken into account when testing for general effect. The retrogressive effect shows itself in negative general effect in tests similar to the training, and is not inconsistent with positive general effect in tests less similar to the training (p. 219).

11. Data from the latter two experiments indicate the important bearing which variability in processes has upon the quantitative treatment of results (pp. 167-176, 181-184). Certain precautions need to be taken in order that the results of the test-training-test type of experiment may not be misleading (pp. 219-224). It would seem that purely quantitative results are worthless.

12. Introspective description of the processes involved in the successive 'moments' of a single experiment, and of practice-effect upon them, indicates such a complex relationship of the elements or part-processes that are fitted to perform the office of the 'Common Factor' that it seems doubtful if there are any purely 'specific' elements in the conscious process. The 'Common Factor' may be constituted of formal modes of consciousness (emotional and volitional attitudes, modes and habits of consciousness, control of attention) in which case it effects 'Spread of Training'; or it may be constituted of the material of consciousness (imagery, systems of imagery, direct and representative) in which case it effects 'Transference' of the elements of experience. Search for the common factor should not be so conducted as to locate only the latter form; experimental evidence indicates that the former is more largely

responsible for the general effect of special practice. In both forms it is selected[3] from former experience and applied with some degree of invention to a more or less novel situation. It would seem that 'adaptability' consists in this 'general' use of the forms and elements of experience which had their origin in 'specific' reactions to specific stimuli,' and that the desideratum of the 'learning process' consists in extending the 'general' applications as widely as possible.[4] There is evidence that all modes and elements of experience may be the 'Common Factor'; that all effects of conscious practice are to some extent 'general' effects (pp. 224-233).

13. Discussion throughout the text makes it clear that much further work is needed in this field. With improved method a complete survey of functional relationship between the mental processes should be made. Many outstanding questions await attack: Conditions favoring and limiting 'general' effect, the scope and causes of negative influence, the duration of direct, and of the various 'general' applications of, training-effect, and its dependence upon length and rigor of training and upon kind of work; relative dependence of individual variation in processes upon nature and nurture; dependence of efficiency upon training in a 'best way' of performing a mental task, *etc.*[5]

[3] This selection and application is not necessarily purposeful or even evident to introspection. The value of introspection, as has been pointed out in the text (p. 181), does not rest upon its assertion or denial of relationship between processes, although its testimony concerning this may often be true, but upon a sufficiently complete and accurate analysis of processes that their relationship may be evident. It is particularly competent to show in this way 'Transference' of the elements of experience; 'Spread of Training,' however, is likely to escape detection unless analyses are especially complete, for it is sometimes extremely subtle and evident only through quantitative analysis (as in the Experiment on Reproduction).

[4] Colvin (Some facts in partial justification of the so-called Dogma of Formal Discipline. Univ. Ill. Bull. 1910. 7: No. 26, p. 31; also, The Learning Process. 1911. Pp. 242ff) makes a plea for the application of this principle in school work, and gives "rules for securing transfer," or for securing a "general" training.

[5] The circuitous process of testing and abandoning various methods of work which often retards reagents in course of practice, and the arrest of an occa-

After investigation has profited by adult introspective analysis and it has been carried out with adolescents, trained in introspection, and has been quantitatively checked by results from children, we may perhaps by reason of our intimate knowledge of the functional relationship of mental processes, the integration of experience, the formal learning-process, be able to determine whether the limited time given to formal education should be spent primarily for discipline or for knowledge, whether information and aims belonging to adult vocations are as vital in the educative processes of children as such information and aims as are incidental to the successful functioning of experience through graded steps in a formal training.

14. Meanwhile, experimental research in the psychological laboratory has established certain functional relationships between mental processes more or less simple, and has singled out factors responsible for the transference of improvement from one exercise to another. Its contribution to the general question of formal discipline is important, in that it shows the general effect of special practice; but it is limited in its scope to fairly simple processes, to periods of short training, and, for introspections, to reagents upon whom training does not produce great practice-effect. Were the processes as complex and various as those engaged in the study of Greek, Mathematics, or Science; were the training to extend over four school-years instead of over ten weeks under limiting laboratory conditions; and were the subjects in the plastic period of the 'teens,' it is conceivable that the extent to which the training is general would be found to be greatly in excess of the laboratory figures.

sional reagent upon a low plateau by reason of a peculiarly inept method of work, suggest that training in 'good form' might be the better part of practice, especially in the early stages, but also in the later stages which involve transitions to new coördinations of part-processes. This phase of practice is considered important in athletics, and in the trades involving skilled movements; and Swift (Studies in the psychology and physiology of learning. Am. Jr. Psych., 1903, 14:224) suggests its application to the early stages of learning skill, while Bryan and Harter (Studies on the telegraphic language: The acquisition of a hierarchy of habits. Psych. Rev., 1899, 6:375), by pointing out the end-processes of training, suggest its place in the acquisition of skill in such types of learning as involve hierarchies of habits.

15. The contribution of Experimental Psychology to the educational theory of training is timely, since intensity of work and drill[6] is coming into vogue again. It is found that great effort and rigorous drill are necessary to pass through 'plateaus of growth' or, as Bagley[7] calls them, "sloughs of despond." There seems to be a disposition to find the conditions of training that will "unlock reservoirs of higher power,"[8] and those who find satisfaction in physiological explanations are turning to the theory of the 'synapse'[9] and the "All or None"[10] principle. This increase of power is deemed necessary for the acquisition of such mental habits and such knowledge as, under the conditions of our civilization, constitute a reasonable preparation for complete living.

[6] Beckwith: Drill, a chapter in pedagogy. 1905.
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[7] Bagley: Craftsmanship in teaching. Macm. 1911.

[8] James: Energies of men. Science, 1907. 25: 321; also Am. Mag. Nov. 1907.

[9] Sherrington: Integrative action of the nervous system. Scribner's. 1906.

[10] Stiles: "All or None" principle and its implications. Am. Phys. Ed. Rev. 1910. 15: 1.

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APPENDIX

APPENDIX A

TABLE I.

Improvement as Shown by Tests on Other Functions
Before and After 11 Days' Training on *e-s*
(Text p. 35)

	Reagent Gs						Reagent Cr					
	Speed in Sec.		Accuracy				Speed in Sec.		Accuracy			
			No. of Words						No. of Words			
	Before Training	After Training	Marked B.	Marked A.	Omitted B.	Omitted A.	Before Training	After Training	Marked B.	Marked A.	Omitted B.	Omitted A.
e—s	199.5	85.6	35	45	12	2	133.3	91.8	46	47	5	0
i—t	390	108.6	56	40	3	9	136.9	120.2	37	42	4	8
s—p	111.5	95	9	15	1	0	89.4	66.2	15	10	2	1
c—a	198	124.8	22	19	0	6	116.6	85.6	25	27	0	2
e—r	223	134	53	53	9	7	166.5	135.6	52	58	8	0
Totals	922.5	462.4	140	127	13	22	509.4	407.6	129	137	14	11
a—n	248	177.8	37	39	9	10	172.8	142.2	31	35	15	14
l—o	178	133.5	15	6	1	4	135.8	88.6	16	9	0	1
e—r	214	138	61	40	7	6	212.8	134	62	42	7	4
Totals	640	449.3	113	85	17	20	521.4	364.8	109	86	22	19
Nouns	160	137.8	79	77	2	2	196.7	184.6	66	80	4	11
e—s	175	99.2	38	49	2	0	137.6	93	42	46	2	3
Functions on Same Mt'	922.5	462.4	140	127	13	22	509.4	407.6	129	137	14	11
Diff."	640	449.3	113	85	17	20	521.4	364.8	109	86	22	19
Total	1562.5	911.7	253	212	30	42	1030.8	772.4	238	223	36	30

TABLE II

Improvement Shown by Percentages of Tests after Training to Tests before Training (Text p. 35)

	Reagent Gs. Speed % of After-Test	Reagent Gs. Accuracy % Words Mkd	Reagent Cr Speed % of After Test	Reagent Cr Accuracy % Words Mkd
e-s[1]	.43	1.28	.69	1.11
i-t[2]	.28	.86	.88	.93
s-p	.85	1.11	.74	1.03
c-a	.63	.76	.73	.93
e-r	.60	1.03	.81	1.15
a-n[3]	.71	.99	.82	1.06
l-o	.75	.64	.65	.90
e-r	.64	.97	.63	1.02
Nouns	.86	1.00	.94	.93
e-s	.57	1.05	.68	.98
Functions on				
Same Mat'l	.50	.93	.80	1.03
Diff. Mat'l	.70	.93	.70	.98
Of Total	.58	.93	.76	1.01

[1] The Trained Function.
[2] Employed on Same Material as Training Mat'l, . . . Printed Columns.
[3] Employed on Different Material, . . . Manuscript.

TABLE III

Quantitative Results (Text, p. 39)

Reagent Gs.

	Total Dev. What % of Whole Weight Lifted: Before	Total Dev. What % of Whole Weight Lifted: After	Avg. Dev. in Grams: Before	Avg. Dev. in Grams: After	% of Gain
Tests in Training Series (40-120 grams) (Avg. 80)	12.1%	8.2%	9.7	7.2	25.8%
Objects inside of field (49-113 grams) (Avg. 67.5)	29.7%	22.1%	20.1	14.9	28.4%
Objects outside of field (146-1870) (Avg. 552.7 g.)	52.8%	29.8%	291.9	165.6	43.3%

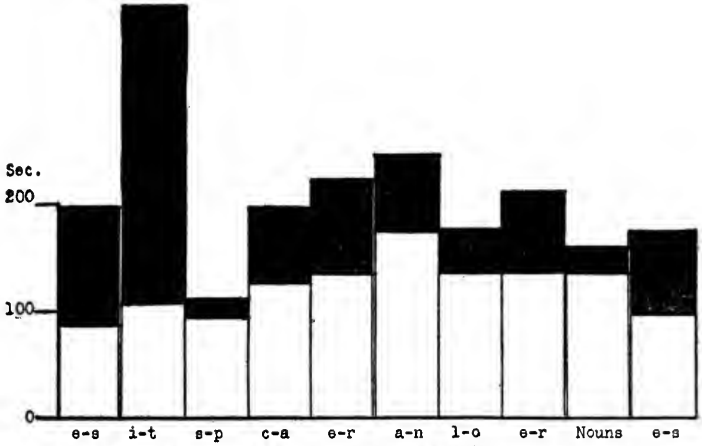

PLATE I. Reagent Gs. Efficiencies (in speed) in other Functions before and after Training on the e-s Function. The filled portion shows amount of improvement. (From Table I.)

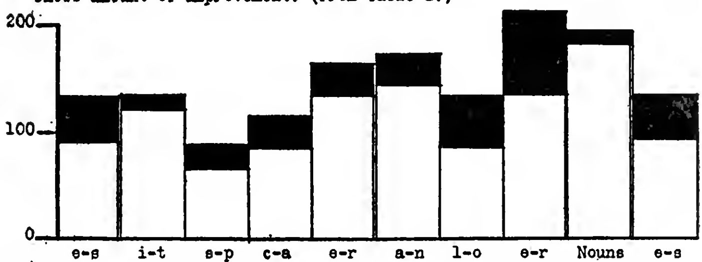

PLATE II. Reagent Cr.

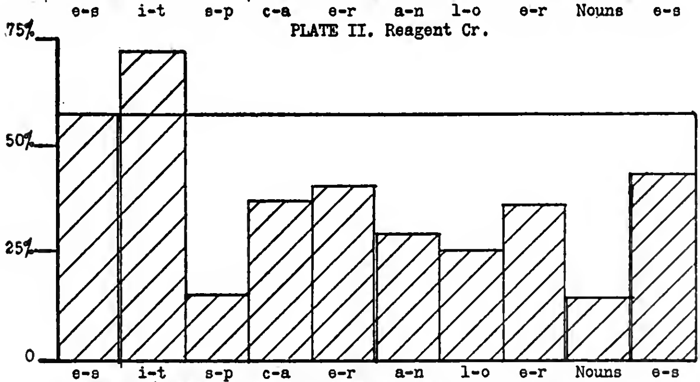

PLATE III. Reagent Gs. Gain shown in per cent. Checked portion shows amount of improvement transferred.

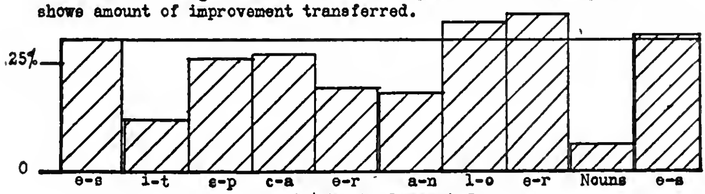

PLATE IV. Reagent Cr.

(See Text, p. 35)

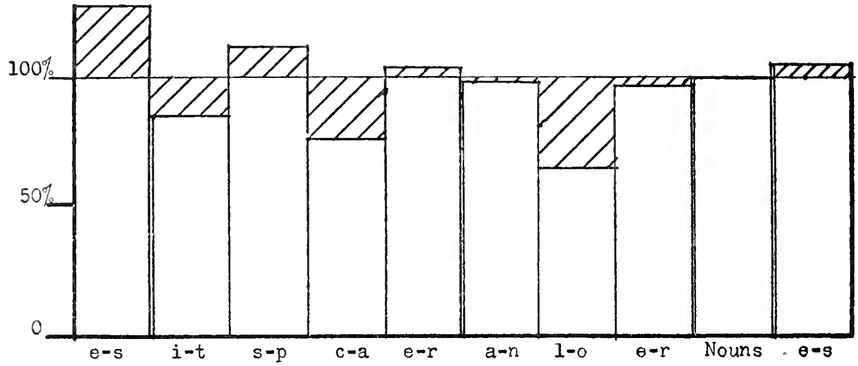

PLATE V. Gs, reagent. Accuracy in percent of initial capacity. Checked portion shows amount of change. (From Table II.)

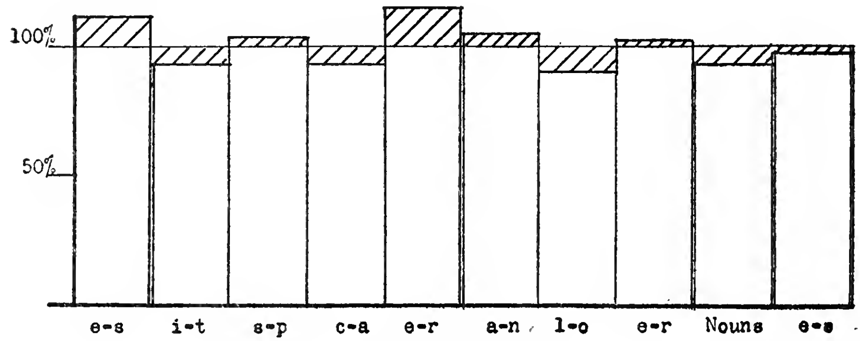

PLATE VI. Reagent Cr.

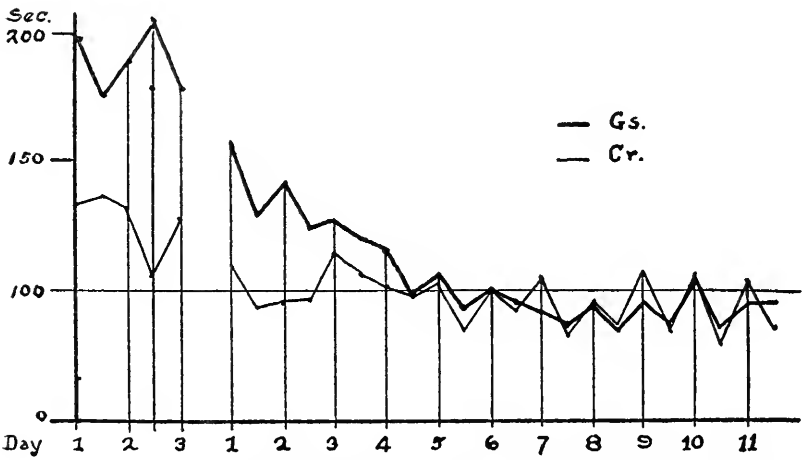

PLATE VII. Practice-Curve from tests taken at beginning and end of each day's training of the e-s Function.

(See Text, pp. 35, 38)

TABLE IV

(Text, p. 39)

Reagent Cr.

	Total Dev. What % of Whole Weight Hefted		Avg. Dev. in Grams		% of Gain
	Before	After	Before	After	
Tests in Training Series (40-120 grams) (Avg. 80 g.)	11.2%	09.0%	8.7	7.2	20%
Objects inside of field (49-113 grams) (Avg. 67.5 g.)	26.1%	18.5%	17.6	12.5	29.2%
Objects outside of field (146-1870 g.) (Avg. 552.7 g.)	15.3%	52.7%	84.8	291.6	-243.9%

TABLE V

(Text, p. 39)

Reagent Gs.

Suggestion Blocks

Wt. of Blocks	Before Training			After Training		
	1st	2d	Total	99th	100th	Total
40	0	+15	15	+5	+5	10
45	+15	0	15	0	+10	10
50	—10	—10	20	—10	+5	15
55	+15	+10	25	—5	+5	10
60	+15	0	15	—5	—10	15
65	—15	+15	30	0	+5	5
70	0	—5	5	0	—5	5
75	0	0	0	+5	0	5
80	+5	+10	15	0	—10	10
85	—20	—20	40	—15	—10	25
90	+15	—5	20	+5	+15	20
95	+15	—20	35	0	+20	20
100	+35	—15	50	0	+10	10
105	0	—5	5	0	—10	10
110	+20	—5	25	+10	—20	30
115	0	0	0	—5	—15	20
120	+5	—10	15	—10	—15	25
Totals	185	145	330	75	170	245
Average			165			122.5
						25.8% Gain

TABLE VI

(Text, p. 39)

Reagent Cr.

	Wt. of Blocks	Before Training			After Training		
		1st	2d	Total	99th	100th	Total
	40	0	0	0	0	0	0
	45	—5	0	5	—5	—5	10
	50	0	—5	5	0	+15	15
	55	+5	+10	15	+5	—5	10
	60	—10	—15	25	0	+10	10
	65	+15	+10	25	+10	+10	20
	70	+5	—15	20	0	+5	5
	75	+20	—25	45	—10	+5	15
	80	—30	0	30	—20	—5	25
	85	0	—10	10	—15	+20	35
	90	+20	+5	25	—10	+15	25
	95	+20	0	20	+15	—5	20
	100	0	+10	10	—10	—10	20
	105	+10	+5	15	—5	—5	10
	110	—20	—10	30	—5	+5	10
	115	0	+5	5	—5	—5	10
	120	—20	—5	25	0	—5	5
Totals	175	175	130	305	115	130	245
Average				152.5			122.5 20% Gain

TABLE VII

(Text, p. 39)

Deviations on Objects

Gs.

Inside Field	Wt.	Before Training 1st	Before Training 2d	Before Training Total	After Training 1st	After Training 2d	After Training Total
1. Big Wt.	81	—31	—6	37	—26	—16	42
2. Bar soap	113	—13	+2	15	+13	—28	61
3. Eraser	67	—22	—17	39	—2	—7	9
4. Pocket Bk.	81	—1	—21	22	—1	—1	2
5. "Outlook"	105	—60	—60	120	—30	—50	80
6. Keys	52	—2	—7	9	—7	+3	10
7. $3 silver	80	+10	+20	30	—5	0	5
8. Small Bottle	63	—18	—13	31	—18	—8	26
9. Elec. bulb	49	+6	+46	52	+21	+26	47
10. Elec. switch	84	+21	+26	47	+6	+11	17
Totals	675	184	218	402	149	150	299
Average				201			149 28.4 Gain

TABLE VIII
(Text, p. 39)

Outside Field							
11. Big Bottle	317	—97	—127	224	—127	+8	135
12. "Outwest"	280	—105	—100	205	—80	—30	110
13. Mucilage	330	—143	—133	276	+67	—33	100
14. Münsterberg	714	—479	—364	843	—114	—214	328
15. Mem. App. Wt.	941	—641	—441	1082	+159	+359	518
16. Ps Molding	146	—16	—16	32	—16	—6	22
17. Hammer	310	—165	—120	285	—135	+65	200
18. Tin Box	462	—257	—162	419	—62	+38	100
19. Key Mem.	154	—24	—9	33	+6	—4	10
20. Psy. Rev.	1870	—1370	—1070	2440	—920	—870	1790
Totals	5527	3297	2542	5839	1686	1627	3313
Average				2919.5			1656.5
							43.3% Gain

TABLE IX
(Text, p. 39)
Deviations on Objects

Cr.

Inside Field	Wt.	Before Training 1st	Before Training 2d	Before Training Total	After Training 1st	After Training 2d	After Training Total
1. Big Wt.	81	—1	—6	7	—11	—11	22
2. Bar Soap	113	—13	—38	51	—3	+2	5
3. Eraser	67	—17	—22	39	—7	—7	14
4. Pocket Bk.	81	+19	+29	48	—21	+29	50
5. "Outlook"	105	—5	—5	10	—15	—5	20
6. Keys	52	—2	—7	9	+13	+8	21
7. $3 Silver	80	+20	+40	60	+15	+20	35
8. Small Bot.	63	—7	+27	34	—18	—18	36
9. Elec. Bulb	49	—4	+41	45	+1	—4	5
10. Elec. Switch	84	—24	+26	50	+26	+16	42
Totals	675	112	241	353	130	120	250
Average				176.5			125
							29.2% Gain

TABLE X
(Text, p. 39)

Outside Field							
11. Big Bottle	317	—117	—117	234	—77	—77	154
12. "Out West"	280	—5	+120	125	+70	+20	90
13. Mucilege	333	+67	+17	84	+667	+567	1234
14. Münsterberg	714	—214	—114	328	+286	+86	372
15. Mem. App. Wt.	941	+59	+59	118	+59	+59	118
16. Pc Molding	146	+104	+104	208	—21	—16	37
17. Hammer	310	—10	+90	100	+40	+90	130
18. Tin Box	462	—87	—62	149	+238	—162	400
19. Key Mem.	154	+4	+96	100	—14	—24	38
20. Psy. Rev.	1870	+130	—120	250	+1130	+2130	3260
Totals	5527	797	899	1696	2602	3231	5833
Average				848			2916.5
							243.9% Loss

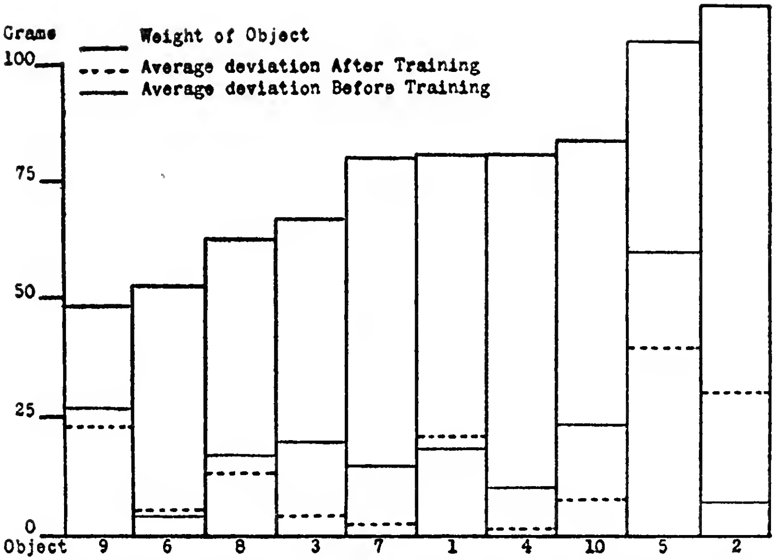

PLATE VIII. Reagent Gs. Weights of Objects Inside the Field, and average deviations of judgments. (From Table VII.)

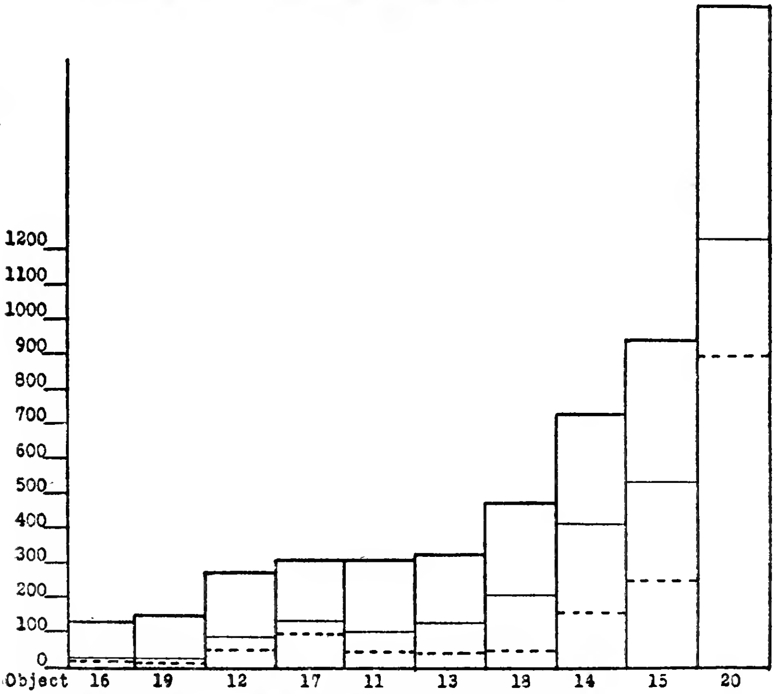

PLATE IX. Reagent Gs. Objects Outside of Field.
(See Text, p. 40)

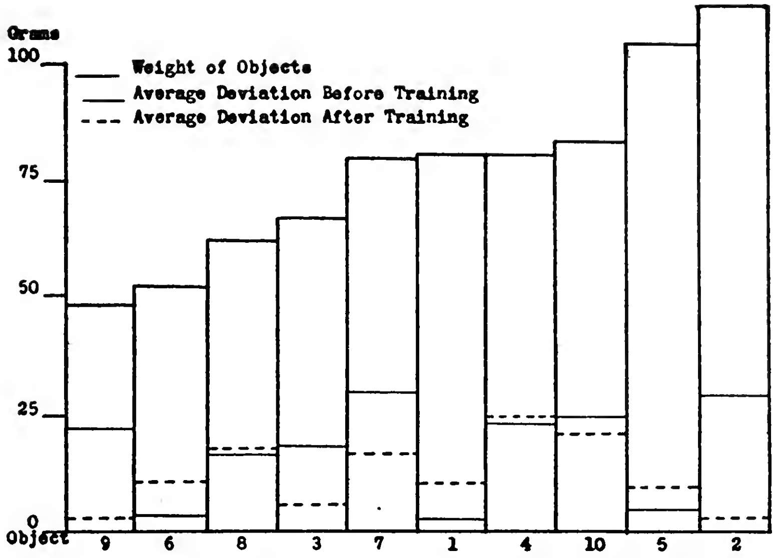

PLATE X. Reagent Cr. Weights of Objects inside the Field, and average deviations of judgments. (From Table IX.)

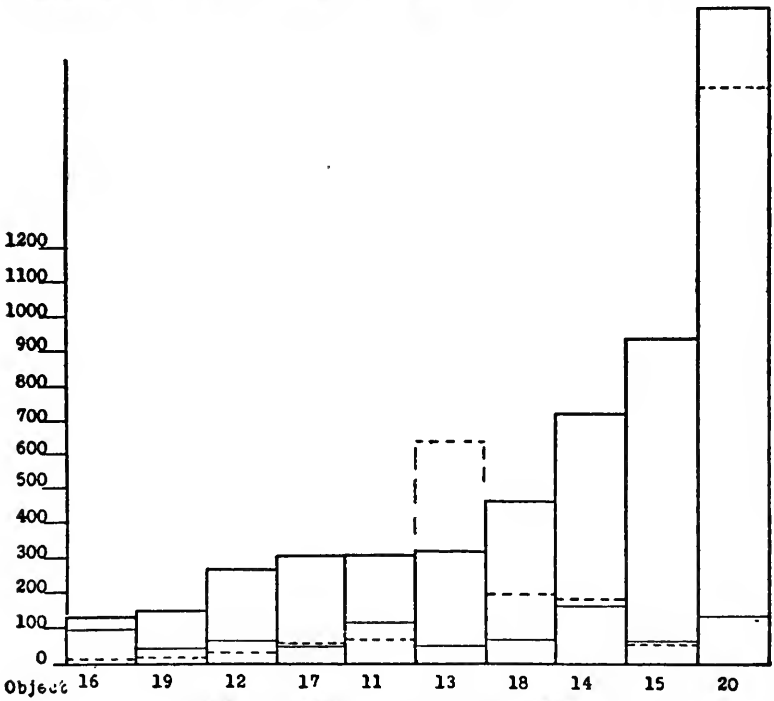

PLATE XI. Reagent Cr. Objects Outside of Field.

(See Text, p. 40)

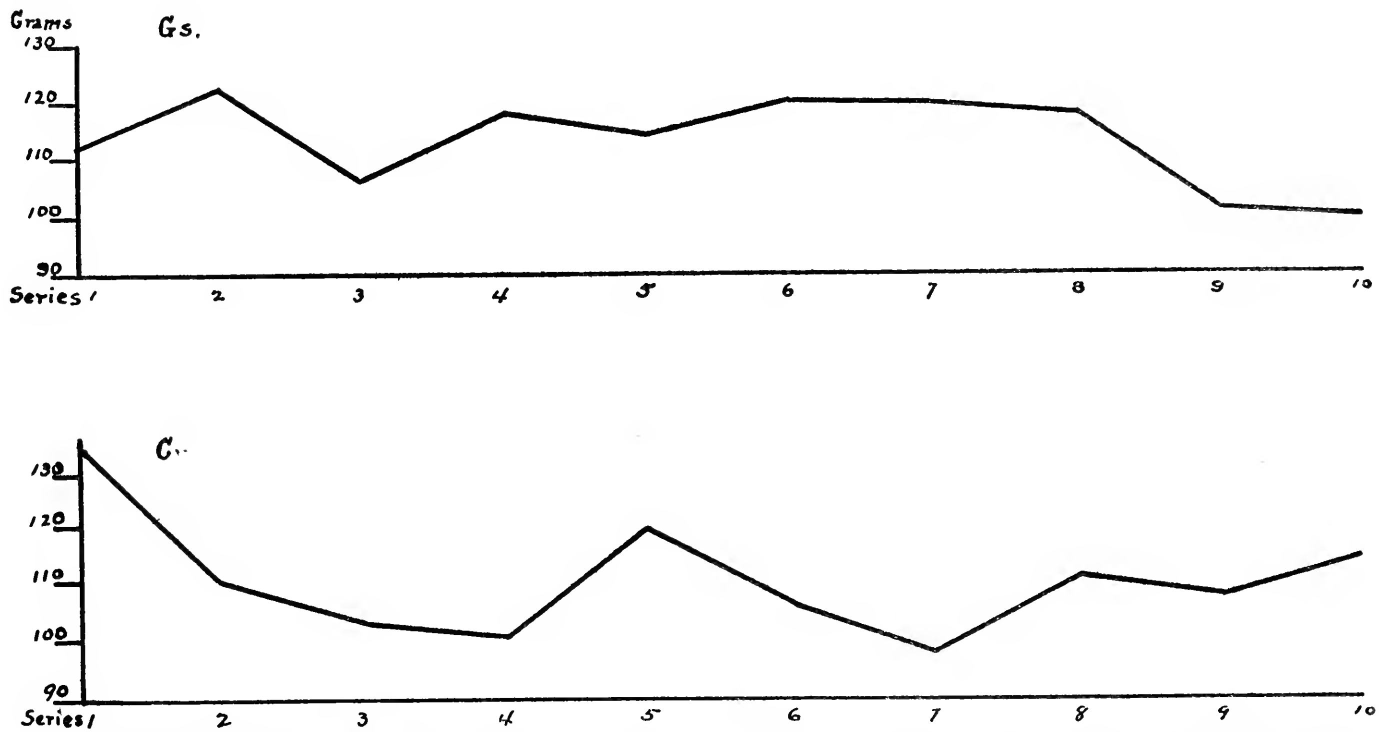

PLATE XII. Practice Curves. Estimating Weights Avg. Deviations for every successive 10 Series.
(170 Judgments in each plot)
(See Text, p. 40)

TABLE XI

Regular Reagents (Text, p. 44)
Brightness-Discrimination. Before Training
(Judgments on 90 variables)

Degrees of White	Aw. R	Aw. W	Aw. U	Aw. % R	Na. R	Na. W	Na. U	Na. % R	Ya. R	Ya. W	Ya. U	Ya. % R
160°	12	0	3	.80	11	1	3	.73	8	2	5	.54
165°	10	3	2	.67	10	0	5	.67	10	3	2	.67
170°	10	1	4	.67	4	2	9	.27	7	4	4	.47
175°	5	8	2	.33	3	2	10	.20	4	4	7	.27
180°												
185°	11	2	2	.73	8	1	6	.54	7	6	2	.47
190°	12	0	3	.80	10	0	5	.67	11	2	2	.73
Totals	60	14	16		46	6	38		47	21	22	
% R	66.7				51.1				52.2			
% U	17.8				42.2				24.4			

(21 Days' Training on Sound during an interval of 64 days)

TABLE XII

(Text, p. 44)
Brightness-Discrimination. After Training
(Judgments on 90 variables)

	Aw. R	Aw. W	Aw. U	Aw. % R	Na. R	Na. W	Na. U	Na. % R	Ya. R	Ya. W	Ya. U	Ya. % R
160°	15	0	0	1.00	14	1	0	.93	12	0	3	.80
165°	13	1	1	.87	8	4	3	.54	5	2	8	.33
170°	10	2	3	.67	7	4	4	.47	4	5	6	.27
175°	10	2	3	.67	4	7	4	.27	1	6	8	.07
180°												
185°	5	6	4	.33	7	1	7	.47	12	2	1	.80
190°	11	2	2	.73	12	2	1	.80	13	0	2	.87
Totals	64	13	13		52	19	19		47	15	28	
% R	71.1				57.8				52.2			
% U	14.4				21.1				31.1			

TABLE XIII

Regular Reagent Cr. (Text, p. 44)
Brightness-Discrimination

Degrees of White	Before Training (Judgments on 76 Variables) R	W	U	%R	After Training (Judgments on 80 Variables) R	W	U	%R
110°	8	0	2	.80	10	0	0	1.00
120°	6	1	2	.67	10	0	0	1.00
130°	5	3	2	.50	8	1	1	.80
135°	6	0	4	.60	4	2	4	.40
140°								
145°	2	2	6	.20	7	2	1	.70
150°	4	0	5	.44	9	1	0	.90
160°	6	0	3	.67	10	0	0	1.00
170°	7	0	2	.78	10	0	0	1.00
Totals	44	6	26		68	16	6	
%R		57.5				85.0		
%U		33.7				7.5		

TABLE XIV

(Text, p. 43)
Sound-Discrimination. Beginning Training
(Judgments on 60 Variables)

Intensity	Aw. R	W	U	%R	Na. R	W	U	%R	Ya. R	W	U	%R	Cr. R	W	U	%R
23.57	3	5	2	.30	5	3	2	.50	3	6	1	.30	4	3	3	.40
25.06	2	5	3	.20	3	3	4	.30	1	5	4	.10	5	4	1	.50
26.48	1	5	4	.10	5	0	5	.50	5	3	2	.50	6	0	4	.60
27.83																
29.12	6	1	3	.60	1	3	6	.10	4	1	5	.40	4	3	3	.40
30.35	5	2	3	.50	3	2	5	.30	6	1	3	.60	4	3	3	.40
32.68	5	2	3	.50	5	4	1	.50	7	2	1	.70	4	4	2	.40
Totals	22	20	18		22	15	23		26	18	16		27	17	16	
%R			36.7			36.7				43.3			45.0			
%U			30.0			38.3				26.7			26.7			

TABLE XV

(Text, p. 43)
Sound-Discrimination Ending Training
(Judgments on 60 Variables)

Intensity	Aw.				Na.				Ya.				Cr.			
	R	W	U	% R	R	W	U	% R	R	W	U	% R	R	W	U	% R
23.57	6	4	0	.60	5	2	3	.50	5	4	1	.50	6	4	0	.60
25.06	3	5	2	.30	4	2	4	.40	3	5	2	.30	6	4	0	.60
26.48	2	3	5	.20	4	3	3	.40	3	2	5	.30	6	2	2	.60
27.83																
29.12	8	2	0	.80	5	2	3	.50	5	0	5	.50	6	2	2	.60
30.35	6	2	2	.60	2	5	3	.20	4	2	4	.40	4	4	2	.40
32.68	6	4	0	.60	5	5	0	.50	4	4	2	.40	6	2	2	.60
Totals	31	20	9		25	19	16		24	16	20		34	18	8	
% R		51.7				41.7				40.0				56.7		
% U		15.0				26.7				33.3				13.3		

TABLE XVI

Control Reagents. (Text, p. 44)
Brightness-Discrimination. Before Interval
(Judgments on 60 Variables)

Degrees of White	Rl.				An.				Wr.			
	R	W	U	% R	R	W	U	% R	R	W	U	% R
160°	8	0	2	.80	4	2	4	.40	8	1	1	.80
165°	7	1	2	.70	5	3	2	.50	7	3	0	.70
170°	5	4	1	.50	4	2	4	.40	7	2	1	.70
175°	4	2	4	.40	4	3	3	.40	7	3	0	.70
180°												
185°	7	2	1	.70	6	2	2	.60	10	0	0	1.00
190°	10	0	0	1.00	8	1	1	.80	7	3	0	.70
Totals	41	9	10		31	13	16		46	12	2	
% R		68.3				51.7				76.7		
% U		16.7				26.7				3.3		

(46 Days' Interval Without Training)

TABLE XVII

Brightness-Discrimination. After Interval
(Judgment on 60 Variables)

Degrees of White	Rl.				An.				Wr.			
	R	W	U	% R	R	W	U	% R	R	W	U	% R
160°	9	0	1	.90	4	3	3	.40	9	1	0	.90
165°	8	1	1	.80	3	4	3	.30	10	0	0	1.00
170°	3	1	6	.30	4	2	4	.40	5	2	3	.50
175°	4	4	2	.40	4	5	1	.40	4	3	3	.40
180°												
185°	5	2	3	.50	7	0	3	.70	6	4	0	.60
190°	9	1	0	.90	8	1	1	.80	9	0	1	.90
Totals	38	9	13		30	15	15		43	10	7	
% R		63.3				50.0				71.7		
% U		21.7				25.0				11.7		

TABLE XVIII

(Text, p. 44)
Comparison of Data (Absolute Amounts)
Regular Reagents

A. Right Judgments

	Aw.	Na.	Ya.	Cr.	Total
Tests					
No. R. Before	60	46	47	46	199
No. R After	64	52	47	68	231
Difference	+4	+6	0	+22	+32
Training in Sound					
No. R at Beginning	22	22	26	27	97
No. R at End	31	25	24	34	114
Difference	+9	+3	—2	+7	+17

B. Undecided Judgments

	Aw.	Na.	Ya.	Cr.	Total
Tests					
No. U Before	16	38	22	27	103
No. U After	13	19	28	6	66
Difference	—3	—19	+6	—21	—37
Training in Sound					
No. U at Beginning	18	23	16	16	73
No. U at End	9	16	20	8	53
Difference	—9	—7	+4	—8	—20

Control Reagents

C. R and U Judgments

	Rl.	An.	Wr.	Total
Tests				
Before and After Interval Without Training				
No. R Before	41	31	46	118
No. R After	38	30	43	111
Difference	—3	—1	—3	—7
No. U Before	10	16	2	28
No. U After	13	15	7	35
Difference	+3	—1	+5	+7

TABLE XIX

(Text, p. 44)

Comparison of Data (Relative)

(All per cents are reckoned upon the whole number of judgments represented in table)

Regular Reagents

A. Right Judgments

	Aw.	Na.	Ya.	Cr.	Total
Tests					
Per cent R Before	66.7	51.1	52.2	57.5	56.9
Per cent R After	71.1	57.8	52.2	85.0	66.0
Difference	+4.4	+6.7	0	+27.5	+9.1
Training in Sound					
Per cent R Beginning	36.7	36.7	43.3	45.0	40.4
Per cent R End	51.7	41.7	40.0	56.7	47.5
Differences	+15	+5	—3.3	+11.7	+7.1

B. Undecided Judgments

	Aw.	Na.	Ya.	Cr.	Total
Tests					
Per cent U Before	17.8	42.2	24.4	33.7	29.4
Per cent U After	14.4	21.1	31.1	7.5	19
Difference	—3.4	—21.1	+6.7	—26.2	—10.4
Training in Sound					
Per cent U Beginning	30	38.3	26.7	26.7	30.4
Per cent U at End	15	26.7	33.3	13.3	22
Difference	—15	—11.6	+6.6	—13.4	—8.4

Control Reagents

C. R and U Judgments

	Rl.	An.	Wr.	Total
Tests				
Before and After Interval Without Training				
Per cent R Before	68.3	51.7	76.7	65.5
Per cent R After	63.3	50	71.7	61.7
Difference	—5	—1.7	—5	—3.8
Per cent U Before	16.7	26.7	3.3	15.5
Per cent U After	21.7	25	11.7	19.4
Difference	+5	—1.7	+8.4	+3.9

TABLE XX

(Text, p. 51)

Orders for Cards

123621453463154256413243526516526153342314

Continue Orders 1 & 4—612451364
Continue Orders 2 & 5—652361346
Continue Orders 3 & 6—652451362

Changes of Equivalence

	R.	Y.	G.	B.	Br.	Bl.
Order 1	1	2	3	4	5	6
Order 2	6	1	2	3	4	5
Order 3	5	6	1	2	3	4
Order 4	4	5	6	1	2	3
Order 5	3	4	5	6	1	2
Order 6	2	3	4	5	6	1

Colors:
*R*ed
*Y*ellow
*G*reen
*B*lue
*Br*own
*Bl*ack

By reversing the above 6 Orders the 12 Orders were made up.

TABLE XXI
(Text, pp. 53, 54, 56, 57)
Reactions on Typewriter (per 100)

A. *Before Training*

Cl.		Al.		Cr.		Bs.	
Sec.	Errors	Sec.	Errors	Sec.	Errors	Sec.	Errors
71	2	94	0	73	3	108.5	8
71	0	104	4.5	74	4	105.4	2
73	1	102	5	71.6	1	99.3	3
79	1	85	1	83	4	99.7	7
81	1.5	81	5	75	3.5	96.4	6
79	0.5	86	2	72.5	3	87.7	5
72	0	78	1	71.2	4.5	79.4	4
75	2	82	5	71	4.5	88.2	1
71	0	80	1	69.8	4.5	83.2	3
71	1	79	6	71	4	94.7	4
73	3	76	3	71.5	1	89.7	0
66	1	75.6	8	73.2	4	93.2	5
66.8	2.6	75.4	5.5	68.2	4	82.5	4
68.4	0	75.8	7	69.5	3.5	80.8	3
69.4	0	70.4	5	69	2	71.8	1
68	0	70.8	6	67.4	0	101.1	4.5
65.8	2	70.4	7	67.4	6	84.5	4
73.1	0	82.2	4	69.4	3	85.5	6
70.4	0	81.2	5	71.3	5	84.1	4
69	0.5	81.7	4.5	67.8	6	79.6	3
64.8	1	79.1	4.5	68.4	6	81	2
70.4	2.5	77.9	7.5	66.8	3	78.6	5
66.1	1.5	73.8	3	68.1	2	74.3	4
65.7	0.5	69.5	7	67.1	3	85.5	11
59.4	0	74.6	6	66.4	4	81.6	7
64.8	2.5	73.8	10	68.1	2	74.5	2
63.8	0.6	74.7	8	65.3	1	75.8	3
63.5	1	73.1	8			80.9	6
62.4	0	70.5	2.5			82.6	7
						77.1	5
						76.3	3

B. *After Training*

Cl.		Al.		Cr.		Bs.	
Sec.	Errors	Sec.	Errors	Sec.	Errors	Sec.	Errors
64.3	0	67.9	9	65.2	3	69.6	10
64	1	64.2	6.5	64.3	5	68.3	8
61	0.5	62.6	5.5	69.2	6	72.8	8
63.5	1.5	65.6	11	68.2	5	69.4	8
62.9	1.5	64.3	10	66.3	5	72.7	5
63	2.5	66.3	6	65.2	4.5	71.6	8
61.2	1	63.1	12	60.8	2	68.8	3.5
60.9	1.5	61.8	11	61.2	5.5	69.2	2
62.3	1	62.1	15	61.5	7	71.8	5
61	1	66.5	11	63	3	65.7	0.5
61.6	1.5	61.5	8.5	64.2	6	69.3	7
60.9	0	62.3	10.5	62	5	69	2
62.6	2	63.2	17	62.2	4	66.4	8
57.9	0	60.5	11.5	58.8	0	65.5	3
61.9	1.5	60.8	13.5	62.5	5	59.2	3
60.6	1.5	58.9	10	61	7	69.5	11
60.5	1	60.9	15.5	63.5	8	70.7	10
59.2	0.5	61.6	13	61.9	9.5		

TABLE XXII

(Text, pp. 53, 55, 56)
Reactions on Typewriter (Avg. per 100 per Day)

A. *Before Training*

Cl.		Al.		Cr.		Bs.	
Sec.	Errors	Sec.	Errors	Sec.	Errors	Sec.	Errors
71	2	94	0	73	3	99.5	5
76	0.9	93	4	76.0	3	87.3	3
73.5	1.1	80.0	3	71.2	3.5	84.0	4.5
67.4	1	73.1	6.3	69.1	3	80.1	5.3
69	1.0	79.3	4.5	69.1	5	77.9	4.3
63.3	0.8	72.7	7	67	4		
B. *After Training*							
63.3	1	65.2	8	66.4	4.5	70.7	8
61.3	1	62.9	11	62.1	4.5	69	3.3
60.4	1	61.0	13	61.7	5.4	66.3	6

TABLE XXIII

(Text, pp. 53, 56, 57)
Reactions on Typewriter (per 100) (Control Reagents)

Before Interval

Mn.		Ge.		Gs.	
91.1	2	147.3	7	107.1	0
95.7	3.6	125.7	4	79.1	0
91.1	6.5	154.2	3.5	79.9	1.5
93.7	6	157.9	3.5	84.8	2.5
86.1	5	131.8	2.5	85.8	1.5
86.7	8	133.6	2	85.4	1
76.7	3.5	106.2	3		
75.5	3	116.5	2		
76.8	8	119	2		
70.9	8	127.2	0.5		
73	7	111.7	0		
71.7	14	118.1	1		
78.1	5	82.2	1		
73.9	6	90.8	1.5		
76.8	8	95.5	2		
73,7	6	97.4	1		
74	5	106.6	1		
67.4	8	100.6	1		
		99.7	2		
After Interval					
73	4	91.4	1.5	86	0
73.4	3	84.2	1	76.4	2
70.4	7	82.2	0	83.7	0
68.4	2	104.9	3	77.1	0.5
68.7	6	91.7	3	82.5	3
70	5.5	88.7	0	77.4	1
70.7	3	83.4	0.5		
69.6	3	81.7	0		
66.7	5	91.5	2		
64.6	11	95.1	3.5		
63.3	6.5	82.5	1		
62.3	8	82.9	1		

TABLE XXIII (Con.)

Second Group, Control Reagents

Before Interval

Day		Bd.		Bh.		Bs. 2		Cf.	
3/3	1	102	7	100	3	100	7	128.4	1
3/5	2	93.4	14+	84.2	6+	87.6	5	112	1
		92.6	13+	74.4	8+	82.8	1	118	1
		87.4	7+	75	5+	75.8	4+	100.8	0
		86.6	5+	78	5	72	2+	102.6	0
		86	5+	76.8	7	70.8	3+	96	0
		80	7	76.4	7	73	2	93.4	1
3/8	3	84.2	5+	79	0	72.8	3+	92.4	1
		81	7	72.4	1	73	3+	88	2+
		77.4	4	80	4+	68.4	2	80.8	0
		73.2	3+	76.2	2	66.4	3	87.2	0
		79	3+	76.2	3+	68.6	4	87	1
		76	4	73.4	4	68.6	0	88.6	1
3/10	4	71.2	3	76.6	4	62.6	1	81.8	0
		67.1	3	74.2	2	65.6	1	78.2	0
		72.6	4	72.4	6	67	5	88.4	1
		71.6	5+	72.4	11	62.8	3	80.8	2+
		72.8	4	75	5+	61.2	3	80.4	0
		68.8	3	74	6	62.4	4	86.2	1
3/12	5	69.4	2	71.8	7+	64.8	3	80.8	1
		66	0	67.4	8	62.6	1	77.8	0
		68.6	3	66.4	8	63	6	76.8	0
		67	7	64.8	13+	67.6	4+	75	0
		66.6	2+	65.4	7	62.6	3	74.8	0
		67.6	3+	66.2	10	60.4	0	74	0
3/15	6	65.6	1	70	7	61.6	4+	73.6	1
		63.2	1+	66.6	6	69.4	1	68	0
		66.2	3+	63	7	60	2	70.4	1
		64.6	5	62.2	5	62.4	3	74	0
		65.4	4	64.6	11	60.4	6	71.4	2
		65.4	2	60.6	5	62.2	4	75.2	0+

After Interval

Day		Bd.		Bh.		Bs. 2		Cf.	
	1	64.6	2+	70.4	2	63	2	75.2	2
		62.6	4	62.6	6	58.6	3	65.2	1
		65	2+	62.4	5	60.6	4	69.4	0
		63.8	2	58.0†	4	60.4	6	71.6	1+
		66	4	61.4	5+*	59.6†	2	65.2	1
		65	6	61.4†	8+*	57.6†	4+	62.2	1
	2	62.8	4	64.4	4	58	7	67.6	2
		63.4	4	60	4	58.4	4	64.4	2
		60	5	61.2	7	56.6	6	68	0
		61	5+	61.6	4+	54	4	67	0
		61	3+	59.6	6	54	3	70.4	1
		59.2	7+	57.8	5	55	5	66.2	0
	3	58.6	7	59.6	3	54.8	4+*	65.8	2
		56.8	3	56.6	6+	57.6	3	57	0
		61	7+	59	8+	57.6	5	64.2	0
		60	8	60	5	58.2	3	65.0	2+
		58.6	7	61.6	7	59.2	4	68.6	0

* Over 10 reactions one place late,—a distinct process of reaction which greatly decreases the time.

† Memory of the beginning of the series.

TABLE XXIV

(Text, p. 56)

Reactions on Typewriter (Avg. per 100 per Day) (Control Reagents)

Before Interval

Mm.		Ge.		Gs.	
90.7	5	141.8	4	87	1
74.1	7.5	116.5	1.3		
74	6.3	96.1	1.5		
After Interval					
70.7	4.5	90.5	1.3	80.5	1
66.2	7	86.2	1.3		

TABLE XXIV (Con.)

Second Group Control Reagents

Before Interval

Bd.		Bh.		Bs. 2		Cf.	
102	7	100	3	100	7	128.4	1
87.7	8.5	77.5	6.3	77.0	2.8	103.8	0.5
78.5	4.3	76.2	2.3	69.6	2.5	87.3	0.8
70.7	3.7	74.1	5.7	63.6	2.8	82.6	0.7
67.5	2.8	67.0	7.3	63.5	2.8	76.5	0.2
65.1	2.7	64.5	6.8	62.7	3.3	72.1	0.7
After Interval							
64.5	3.3	62.7	4.8	60.0	3.5	68.8	1.0
61.2	4.7	60.8	5.0	56.0	4.8	67.3	0.8
59.0	6.4	59.4	5.8	57.5	3.8	64.1	0.8

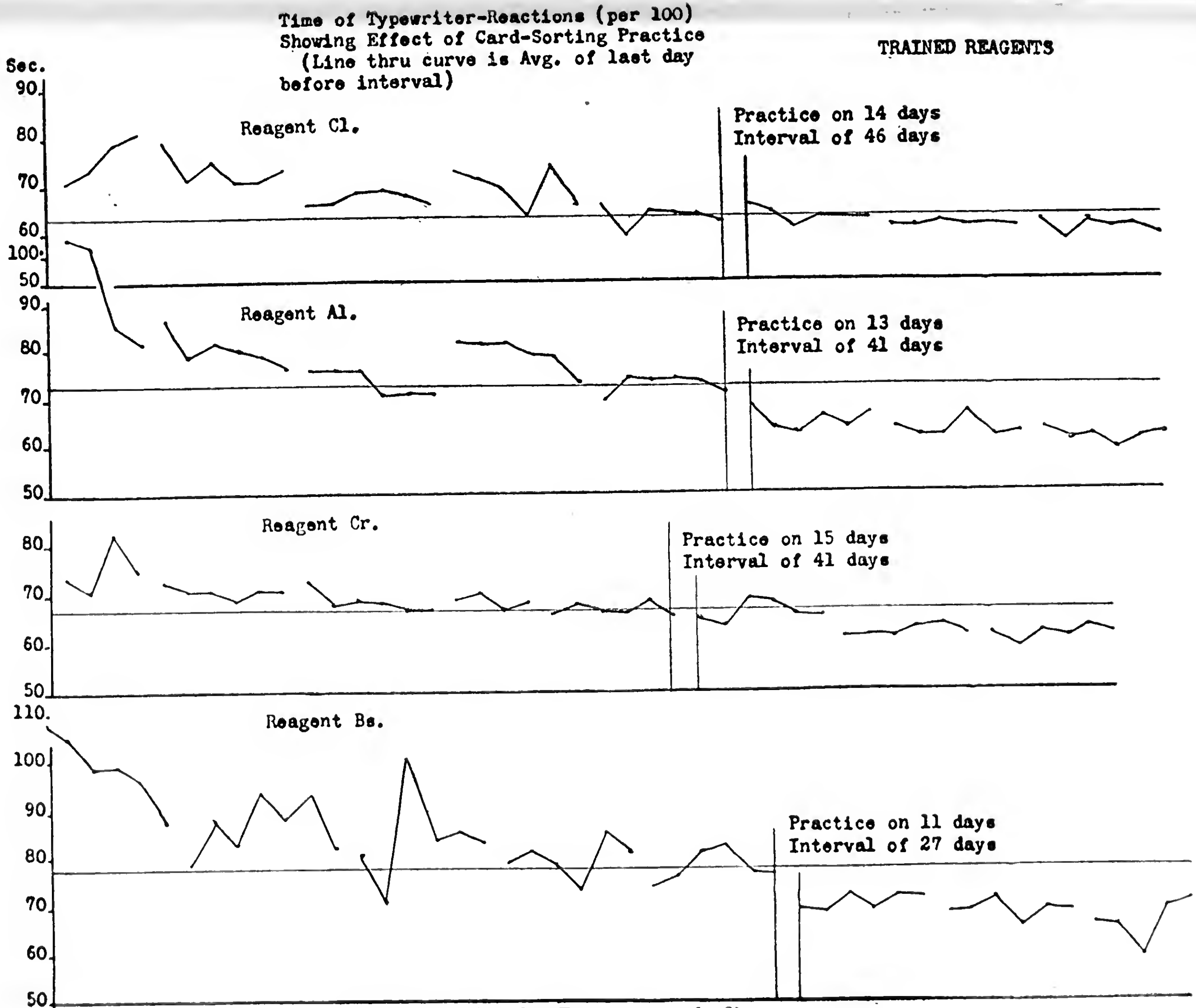

PLATE XIII. (See Text, pp. 53, 56, 58)

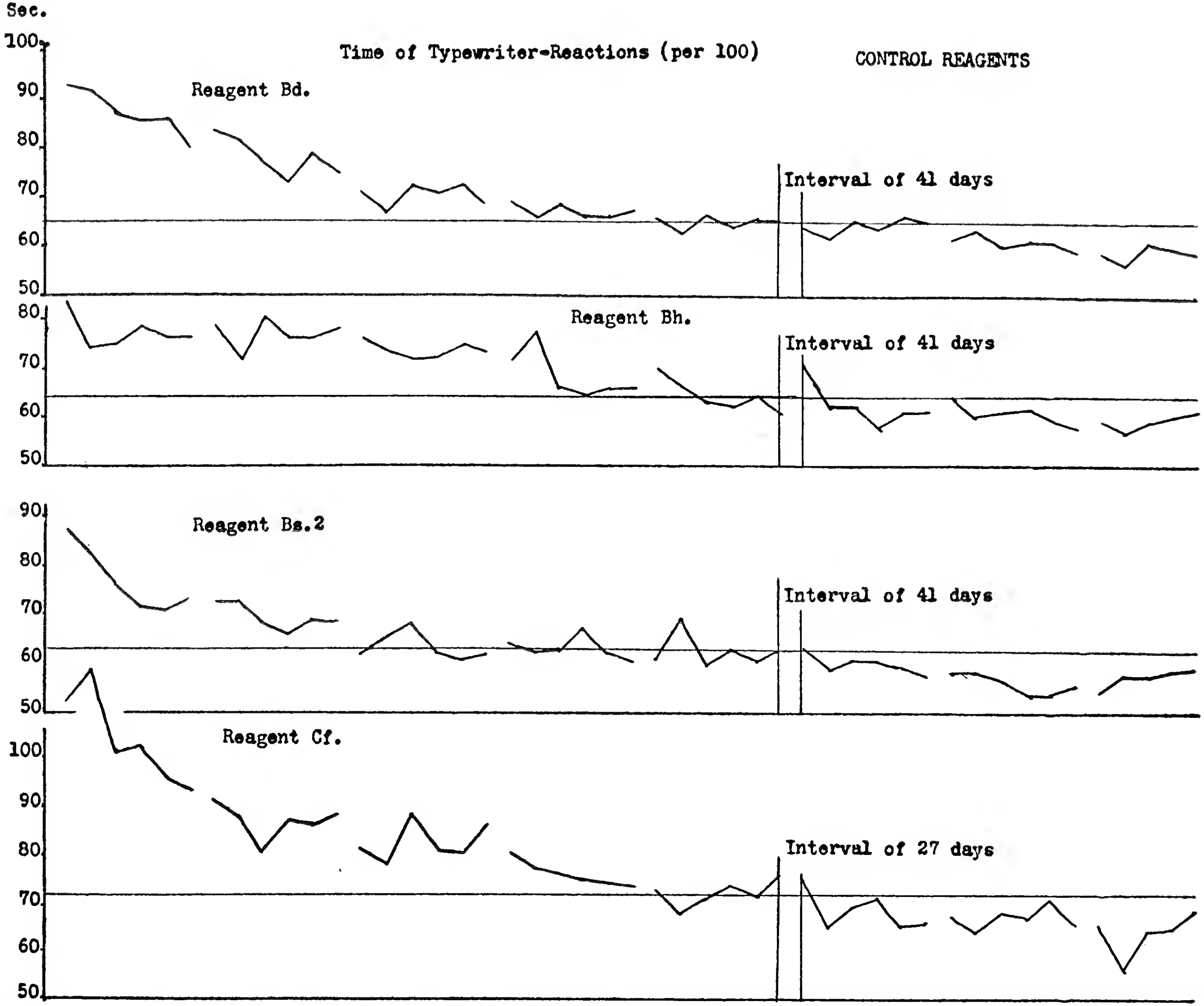

PLATE XIV. (Continued on next page.)

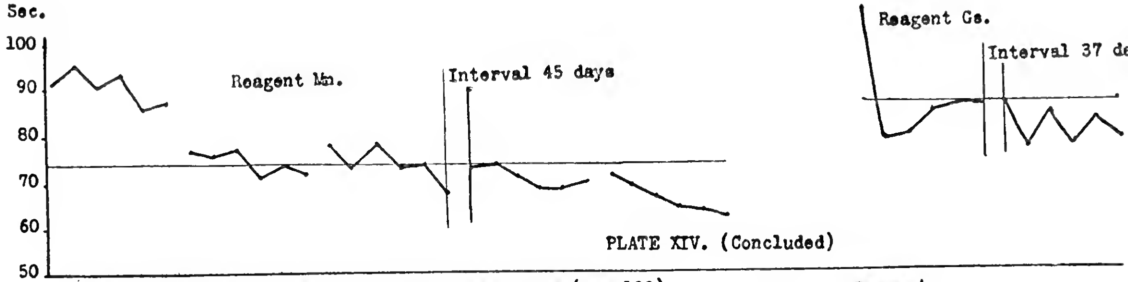

PLATE XIV. (Concluded)

Daily Average of Time of Typewriter-Reactions (per 100)
Showing Effect of Card-Sorting Practice

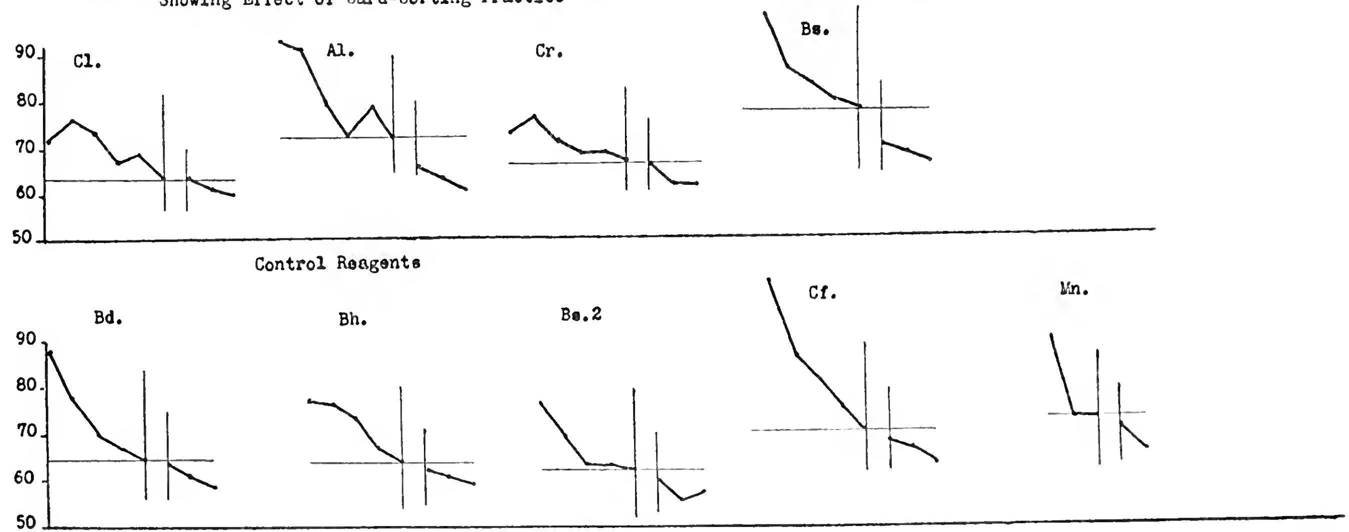

PLATE XV.
(See Text, pp. 56, footnote 58-9)

TABLE XXV
(Text, pp. 53, 54, 56)
Card-Sorting Reaction (per 100)

Cl. Sec.	Cl. Errors	Al. Sec.	Al. Errors	Cr. Sec.	Cr. Errors	Bs. Sec.	Bs. Errors
113	0	*136.6*	2	*130.2*	0	*133.8*	0
100.6	0	134	5	122.4	2	127.6	1
111.2	0	*119.2*	0	*108.6*	3	117.8	4
103.4	0	116.4	2	112	3	129.4	2
96.8	0	*123*	1	*112.2*	2	*124.2*	0
93.2	1	109	2	103.8	2	111.8	3
99.8	1	*103.6*	3	96.2	0	*115*	0
101.8	0	*103.4*	2	97.2	1	107.5	3
92	0			105.4	2	109.5	4
		101.6	4	100.6	6	104.5	2
89.3	0						
89.4	0	97.6	3	98.4	2	*101.4*	1
88.6	0	91.6	1	102.6	7	87.4	5
88	0	91.4	1	*99*	2	100	2
90.4	0	96.2	8	97	1	99.2	2
91.6	0	*92.2*	3	95.4	2	*100.8*	2
87.9	0	94.8	4	88.2	0	96	3
93	0			*91.8*	6	99.2	1
90.6	0	91.8	3	92.4	3	98.4	2
90.4	0	91.6	3	90.6	4	*98.5*	1
90	1	88	2	88.8	2	100.5	4
91.8	0	*89.8*	5	*93.4*	3	96.5	6
93.4	0	88	5	96	2	97.5	3
92.2	0	*90.2*	3	96.2	5	*109*	7
85.4	0	91.4	2	89.8	4	103.5	6
94.8	0	87.2	4	*95.8*	5	*97*	5
90.4	0	91.4	4	92.4	2	95.5	2
84.5	0	*91.8*	4	94.8	5	103	3
81.5	0	96	4	95.2	2	102	5
81.5	0	98	9	*92.4*	1	*92.5*	1
85	2	100.4	7	89.2	2	89	0
89	0	*96.6*	4	*91.5*	1	105	8
85	0	91.8	3	88	3	95.5	1
89.2	1	*96*	4	92	5	*90.5*	3
86.4	0	94.8	3	91.5	3	89.5	2
85.5	0	*88.4*	6	*89.2*	1	89.5	2
82	0	90.4	4	86.2	6	88	1
79.5	0	89.8	7	*97*	4	*92*	5
79	1	94.2	5	97.5	4	90.5	1
81	0			93	2	88	0
83.5	0			96	5	87	1
82	0			*93.5*	6		
81	0			88.5	6		
				91.5	2		
				95.5	14		
				93.5	2		
				94	7		
				92.5	4		
				92	4		
				96	5		
				92	8		
				92	4		
				91	3		

TABLE XXVI

(Text, p. 53)

Card-Sorting Reaction (Avg. per 100 per Day)

Cl.		Al.		Cr.		Bs.	
Sec.	Errors	Sec.	Errors	Sec.	Errors	Sec.	Errors
106.8	0	135.3	3.5	126.3	1	127.2	1.8
107.3	0	117.8	1	110.3	3	118	1.5
97.9	0.5	116	1.5	102.4	1.3	109.1	1.5
90.6	0	102.9	3	102	4.3	97	2.5
89.1	0	94.2	3.3	94.9	1.3	98.6	2
90.8	0	93.5	3.5	90.9	3.8	98.2	3.5
90.2	0.5	90.5	2	93.9	3.5	106.2	6.5
90.7	0	88.9	5	94.6	3.5	99.4	3.8
92.6	0	90	3.3	90.8	1.5	95.5	2.3
83.1	0.5	96.5	6	90.8	3	89.4	2
87	0	94.2	3.5	87.7	3.5	89.4	1.8
87.3	0.5	95.4	3.5	95.9	3.8		
81.5	0.3	90.7	5.5	92.8	6.2		
81.9	0			93.1	5.3		
				91.5	3.5		

TABLE XXVII

(Text, pp. 57, 58)

Comparison of Gains Between Training Periods
Typewriter-Reaction

	Training Reagents (4th and 5th Days, in Practice.)				*Control Reagents* (4th and 5th Days after Interval.)	
	Cl.	Al.	Cr.	Bs.	Mn.	Ge.
Avg. of 2nd and 3rd Days......	70.5	76.6	70.0	86.0	74	105.5
Avg. of 4th and 5th Days......	66.1	76.0	67.9	79	68.4	88.4
Gain	4.4	0.6	2.1	7.0	5.6	17.1
% Gain	6	0.8	3	8	7	16
Avg. last two Days before Card Practice	66.1	76.0	67.9	79		
First two after	62.3	64.0	64.3	69.9		
Gain	3.8	12.0	3.6	9.1		
% Gain	6	16	5	12		

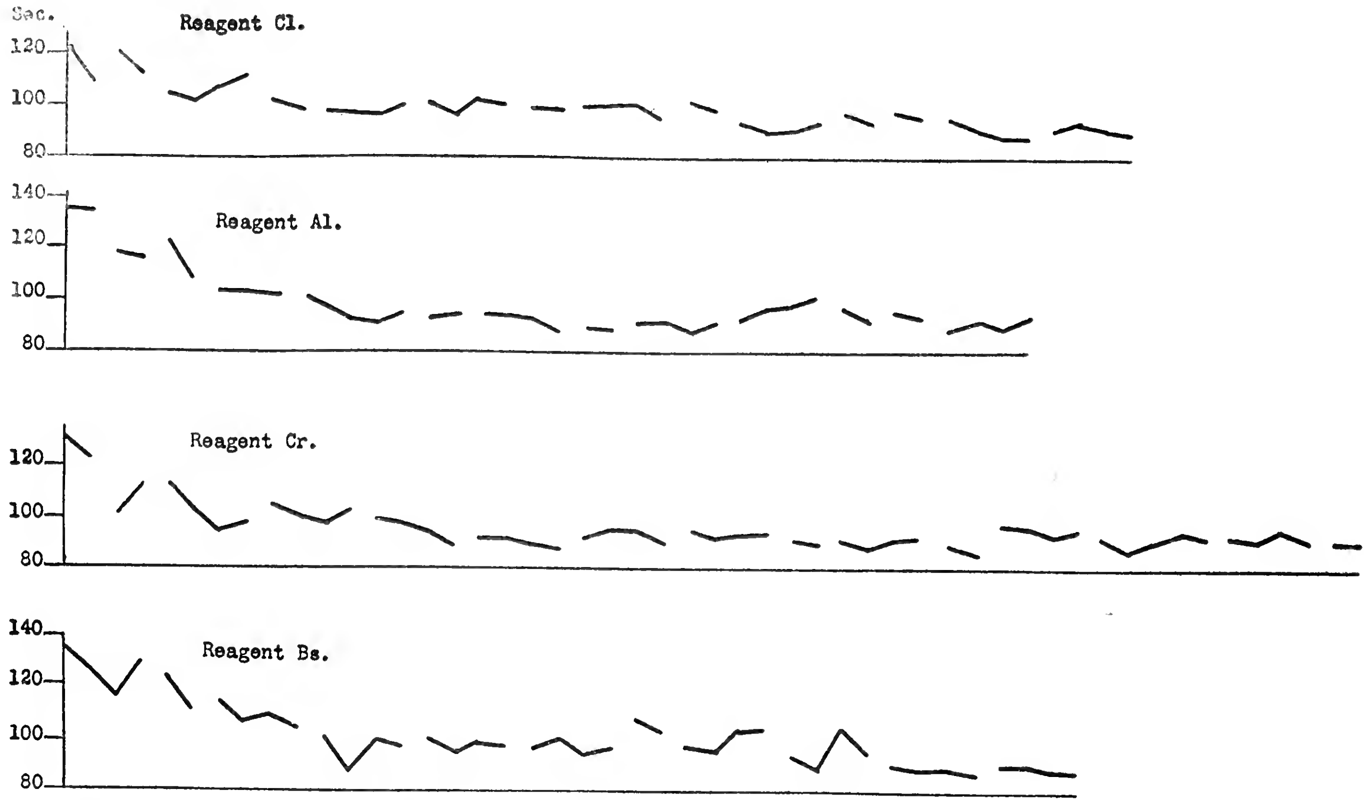

PLATE XVI. Practice Curves of Card-Sorting. Time per 100 reactions. (From Table XXV.)

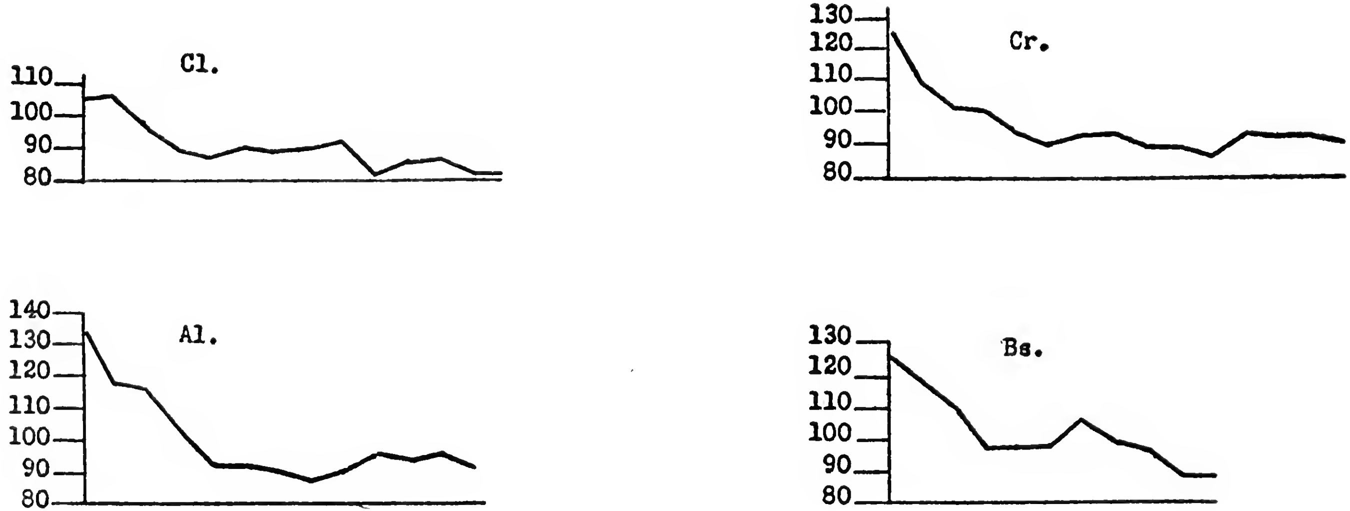

PLATE XVII. Practice Curve. Averages for successive days. (From Table XXVI.)
(See Text, p. 53)

TABLE XXVIII

(See Text, footnote pp. 58-9)

Time per pack of 50 cards, sorted by suit into four compartments, showing the influence of practice in the typewriter-reaction.

Before Interval

	Regular Reagents								Control Reagents			
	Bd.		Bh.		Bs. 2		Cf.		Cn.		Sn.	
	55	0	55.4	0	52.4	0	62.4	1	57.4	0	48.8	0
	57.5	1	51	1	54.6	0	70	0	52.4	0	50.6	1
	55	0	52.6	1	50	0	67	0	53.6	1	49	0
	50	0	48	1	52.6	1	67	0	48	1	50.6	1
Total	217.5	1	207.0	3	209.6	1	266.4	1	211.4	2	199.0	2

After Interval

	Bd.		Bh.		Bs. 2		Cf.		Cn.		Sn.	
	56.6	1	51	1	52.8	5	61.4	0	60	1	51.4	0
	54.2	1	50	2	53.4	5	56.4	0	55	2	49.8	0
	52	0	49.8	3	52.2	3	57	0	53.8	1	50.6	0
	52	4	46.8	3	50.6	3	57	0	52.6	5	52.4	0
Total	214.8	6	197.6	9	209.0	16	231.8	0	221.4	9	204.2	0
Diff.	—2.7		—9.4		—0.6		—34.6		+10		+5.2	
%	—1.2		—4.5		—0.3		—13.0		+4.7		+2.6	

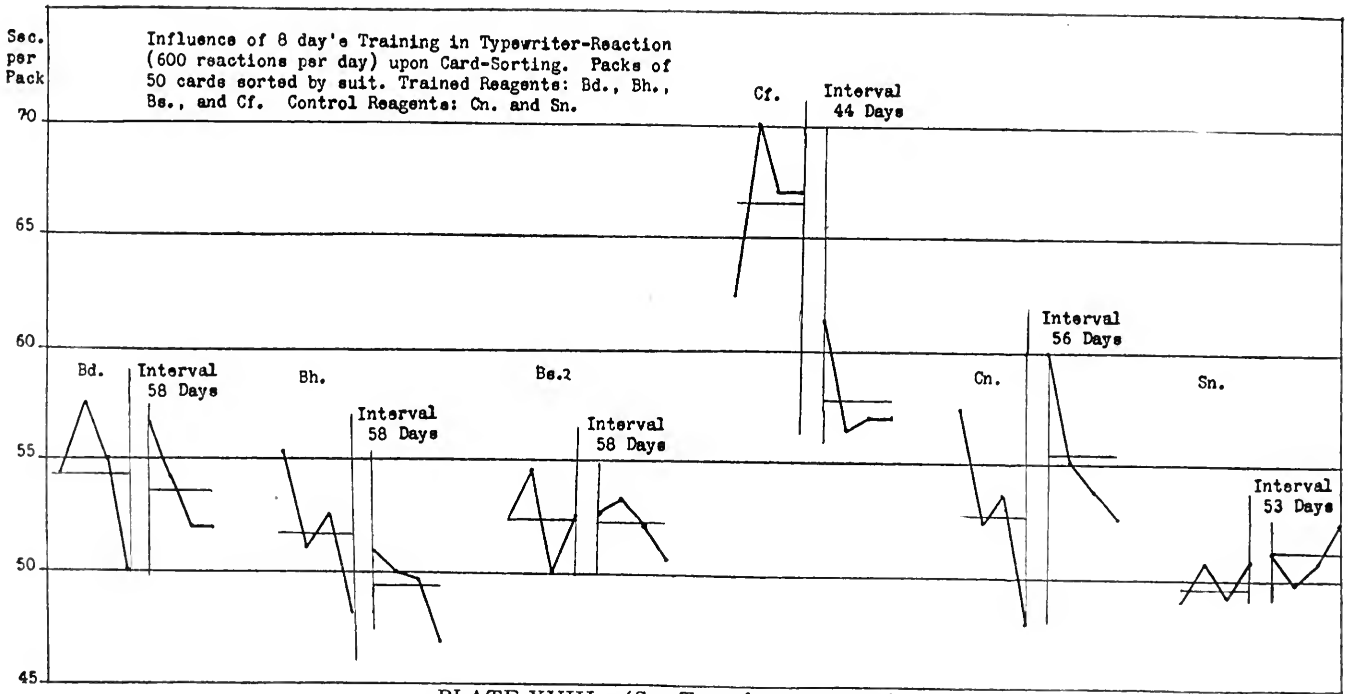

PLATE XVIII. (See Text, footnote p. 59.)

APPENDIX B

(Presenting data relevant to the Experiment on Attention, pp. 76-173.)

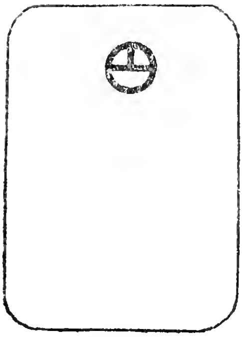

FIG. 1
Symbol on cards

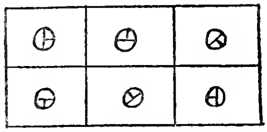

FIG. 2. (See p. 76) Arrangement of compartments in cabinet for card-sorting.

Cardsorting

Instructions to reagents

1. This is a test in "reaction with discrimination and choice." On each of the packs of fifty cards the time and errors will be recorded. Speed, therefore, should be aimed at, yet the sorting should be accurate. Time will be saved if you get a dependable mental scheme of the compartments rather than directly matching the cards, which, although necessary at first, makes sorting wait upon the eye.

2. In the final introspections of the day note:
   (a) Any special hindrances or helps to the sorting,
   (b) Your mental scheme, if any,
   (c) Any development or change in your scheme,
   (d) What demanded attention most? Any tendency to name or pronounce?
   (e) Whether the sorting is fatiguing,
      (1) Any bodily strain,
      (2) Any mental strain,
   (f) Whether sorting is agreeable or otherwise,
   (g) Any change in these respects from previous introspections. (Applicable only after the first day.)

3. In introspections noted between packs mention briefly a few of the more important points about the process of sorting that occur to you.

4. Look over the cards on the cabinet so you will be able to distinguish the symbols readily.

5. The procedure will be:
   (a) Arrange first pack conveniently in hand, and take position comfortably before the cabinet.
   (b) Throw on the table the blank, at announcement of "Go!"
   (c) Sort cards, aiming for speed and accurate work. As last card leaves hand announce "Now!"
   (d) Note brief introspections.
   (e) Like procedure with remaining three packs, taking them in order.
   (f) After the last pack of the day, note your introspections in fuller form.

Fig. 3 (See p. 76)

aatanetntaeneaatanetntaeneeaeneatntenatta tanetnaene

FIG 4. Sample series of stimuli used in the typewriter-reaction (see pp. 52, 76).

Poets	Philosophers	Statesmen	Scientists	Musicians
Homer	Plato	Pitt	Faraday	Beethoven
Virgil	Socrates	Gladstone	Darwin	Wagner
Shakespeare	Aristotle	Washington	Huxley	Mozart
Milton	Kant	Jefferson	Watt	Hayden
Browning	Locke	Lincoln	Tyndall	Bach
Tennyson	Hume	Webster	Agassiz	Mendelssohn
Goethe	Hegel	Roosevelt	Galileo	Handel
Whittier	Pythagoras	Napoleon	Helmholz	Verdi
Poe	Spinoza	Bismark	Newton	Paderweski
Longfellow	Descartes	Burke	Ohm	Paganini

Fig. 5. The names of men in the classes used for Controlled Reaction. (See p. 77)

Series 1	Series 2	Series 3	Series 4	Series 5
Homer	Darwin	Socrates	Aristotle	Browning
Pitt	Virgil	Shakespeare	Hayden	Lincoln
Beethoven	Wagner	Huxley	Kant	Bach
Faraday	Gladstone	Milton	Watt	Tyndall
Plato	Mozart	Washington	Jefferson	Locke

Series 6	Series 7	Series 8	Series 9	Series 10
Hume	Roosevelt	Napoleon	Verdi	Descartes
Agassiz	Galileo	Goethe	Bismark	Ohm
Mendelssohn	Hegel	Helmholz	Paderweski	Paganini
Webster	Handel	Whittier	Poe	Burke
Tennyson	Pythagoras	Spinoza	Newton	Longfellow

Fig. 6. The series of names as presented. (See p. 77)

	(a) Intervals		(b) Series				
No.	Scale	Intensity[1]	1, 2	3, 4	5, 6	7, 8	9, 10
1.	20.16°	.5	1	2	3	4	5
2.	23.57	.7	7	8	9	1	2
3.	25.06	.8	5	6	7	8	9
4.	26.48	.9	2	3	4	5	6
5.	27.83	1.0—Norm	9	1	2	3	4
6.	29.12	1.1	4	5	6	7	8
7.	30.35	1.2	8	9	1	2	3
8.	32.68	1.4	3	4	5	6	7
9.	34.85	1.6	6	7	8	9	1

[1] From Fechner: Psychophysik. S. 181.

Fig. 7. Intervals of intensity, and series as presented in Sound Discrimination. In the Series, No. 2 is the reverse of No. 1. (See pp. 77, 78, 188)

Greater,	>
Less,	<
Like,	|||
Doubtful,	?

FIG. 8. Symbols used in recording judgments in Sound Discrimination. (See p. 78)

Series 1	2	3	4	5
3	4	2	2	1
1	3	4	1	4
4	1	1	3	2
2	4	3	2	3
3	2	2	4	2
2	3	4	2	1
4	2	2	3	3
1	4	3	1	4
3	1	1	4	2
4	3	2	2	1

Intensities[1]

$1 = 10° = 0.12$
$2 = 25° = 0.80$
$3 = 40° = 2.10$
$4 = 60° = 5.00$

[1] From Fechner's Psychophysik, I:181).

FIG. 9. Series of sounds in the test on Memory of Sounds. (See p. 78)

Series of letters and figures

1 (a)	1 (b)	2 (a)	2 (b)	3 (a)	3 (b)	4 (a)	4 (b)	5 (a)	5 (b)
K	4	C	5	P	7	G	6	L	8
S	7	V	8	H	1	L	9	G	2
B	5	J	6	Z	8	C	7	M	9
M	2	B	3	K	5	H	4	P	6
F	6	S	7	B	9	P	8	S	1
P	1	H	2	S	4	F	3	B	5
H	3	W	4	P	6	M	5	K	7
C	8	T	9	C	2	B	1	C	3
L	2	D	3	G	5	S	4	H	6
G	9	K	1	N	3	K	2	P	4

FIG. 10. The series of (a) consonants used in the test on Memory of Consonants, and the series of (b) Digits used in the test on Memory of Numerals; also (c) the pairs presented in the test on Memory of associated Pairs. (See p. 79.)

FIG. 11. The series of symbols used in the test on Memory of Visual Signs. (See p. 79.)

FIG. 12. Reproduction of size and style of letter and spacing used in tests on Learning 12-Consonant-Rectangles. (See pp. 80, 82.)

M——— R ———C
G——— L ———D
C——— M ———N
W——— N ———T
S——— W ———N
Q——— R ———L
N——— T ———R
S——— W ———R
B——— R ———N
W——— S ———M

FIG. 13. The letters used in the test on Word-Completion. (P. 80.)

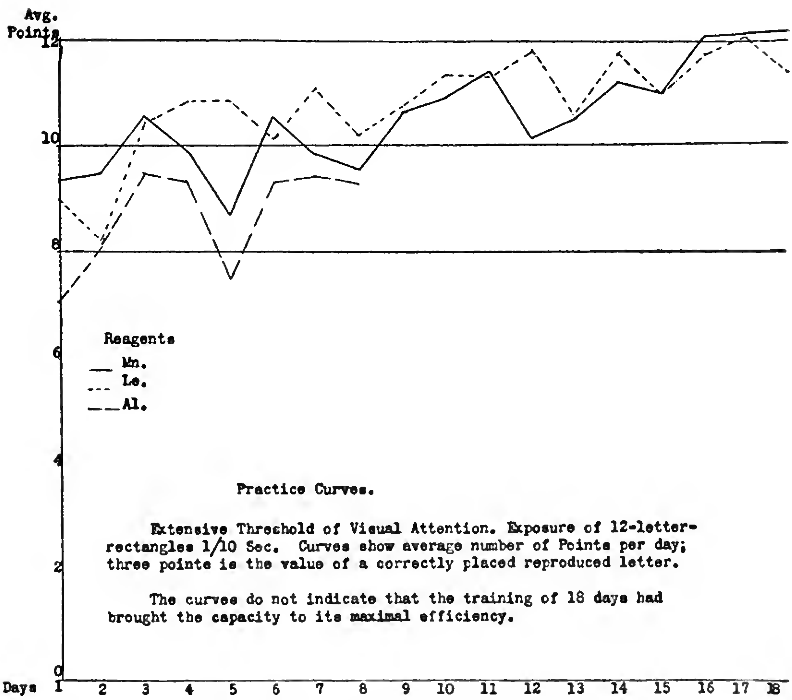

FIG. 14. (See text, pp. 83, 93)

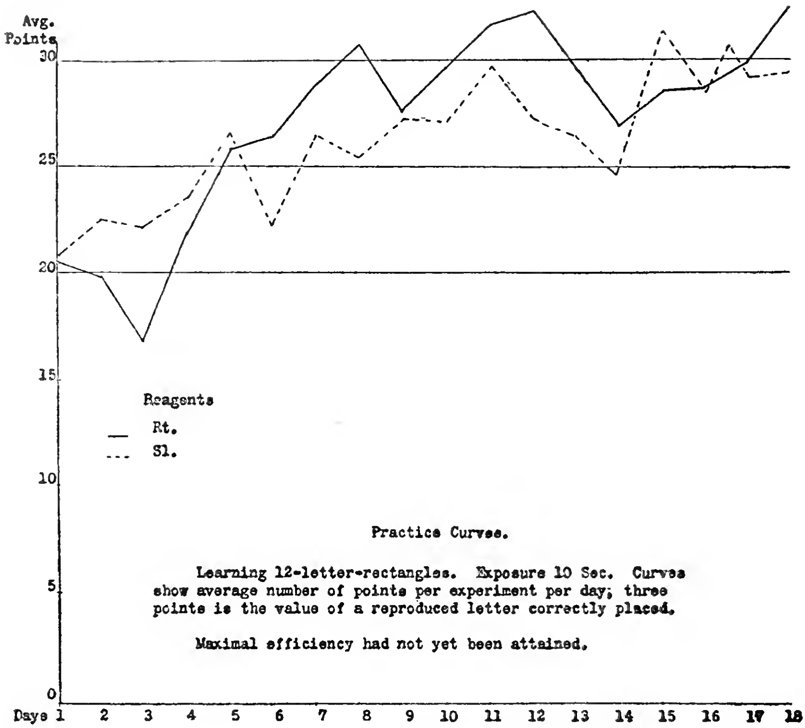

FIG. 15. (See text, p. 94)

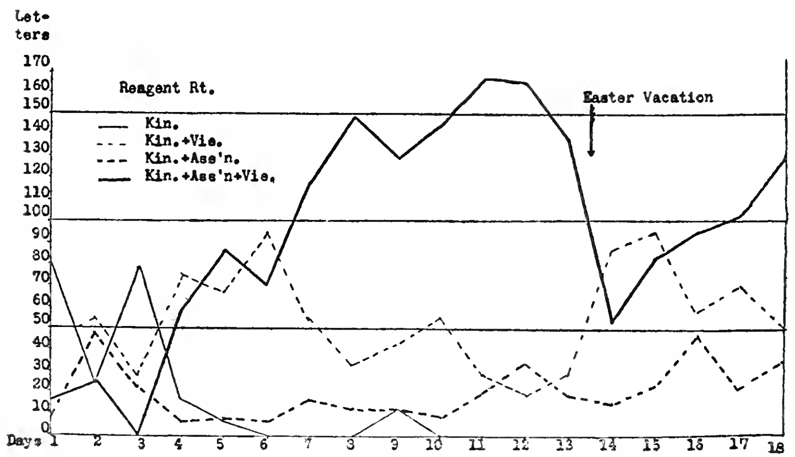

FIG. 16

Analysis of Rt.'s Practice Curve in Learning 12-letter-rectangles, accord-

ing to complexity of process, showing change in complexity during practice. The curves show the number of letters reproduced from rectangles according to the imagery from which they were recorded; *e.g.*, on the first day 80 letters were recorded from rectangles upon which the Kinaesthetic (verbal) imagery alone was used, 40 letters from rectangles upon which Kin. and Visual imagery were coördinated, 17 letters from rectangles for which the three-fold coördination of Kin. + Associations + Vis. imagery was used. (See text, pp. 95, 176.)

At the beginning most of the work was done in Kin. A. imagery which as a single-fold method disappeared on the 6th day. The two-fold method was dominant on the 4th, 5th, and 6th days. From the 7th day the three-fold and four-fold coördinations predominated. The course of practice is toward greater complexity of the process.

Easter vacation caused a lapse to the status of learning of the 6th day, after which the same development in complexity of coördination takes place as that on the 7th and 8th days.

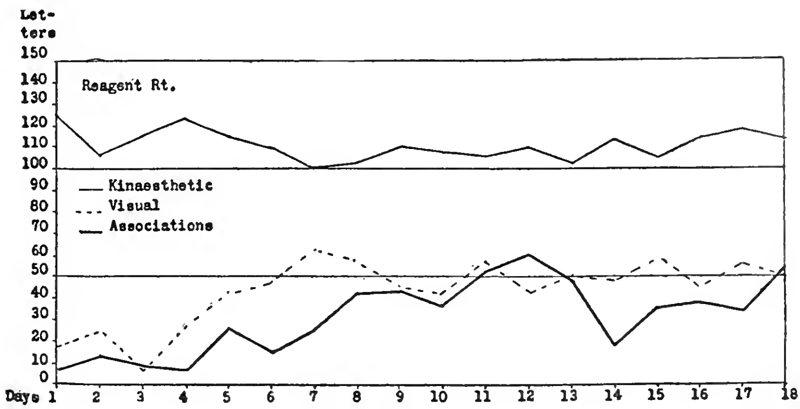

FIG. 17

Analysis of Rt.'s Practice Curve in Learning 12-letter-rectangles, according to the number of letters reproduced from each kind of imagery during the day, disregarding the complexity of method in coördinations, *e.g.*, on the first day 125 letters were reproduced from Kinaesthetic (Verbal) imagery, 18 from Visual imagery, and 8 from Associations. (See text, p. 174.)

Associations for Rt. were usually visual images of words, as "Chemically Pure" for holding the letters C P.

It is evident that the principal rise in the practice curve is caused by the growing frequency of Visual and Association letters, *i.e.*, by the growth in the process of the auxiliary forms of imagery. The letters reproduced on the 12th day are similar to those reproduced on the 3d day in that they are alphabetic symbols; in the mind of the reagent, however, they differ greatly in kind of letter—they are more dominantly visual and visually word-bound symbols, less rote-letters in the muscles of the tongue.

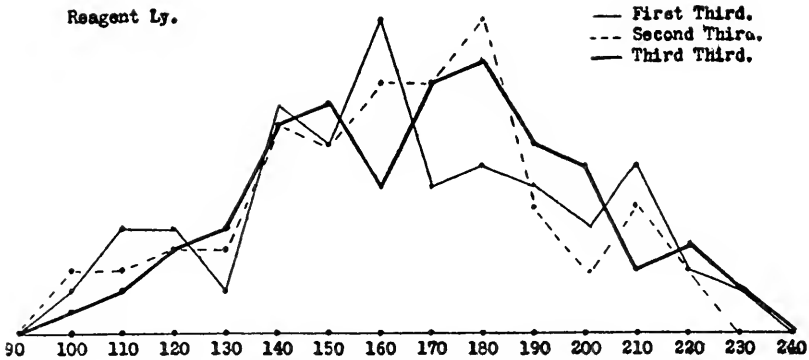

FIG. 18

Curves show distribution of Reaction to Sound in the first, second and third thirds of Ly.'s training (1100 reactions); only the reactions with the Morse key at 100-gram tension being chosen (270 reactions). Reactions from 91 to 100 sigma are plotted on 100. (See text, p. 101).

Practice-effect involved change in processes.

APPENDIX C

Scoring the 12-letter-rectangle

If a single score is to measure the power of reproduction, it must give value to a reproduced letter when it is misplaced in the record; and it would seem that this value should be less than the value given to a correctly placed letter, and should vary with the degree of spatial reproduction as indicated by the amount of misplacement. Any system of values, nevertheless, is arbitrary, since it will favor some methods of learning and reproduction more than others.

Let the following scheme represent the relative positions on a 12-letter-rectangle:

j	c	b	a
k	g	f	d
l	i	h	e

a = Correct position, and may be in any space on the card.
b = Adjacent space on the line.
c = Second remove on the line.
d = Adjacent space in the column.
e = Second remove in the column.
f = Space adjacent at corner.
Etc.

If the reproduced letter belongs in position *a*, in the above scheme, (and that may be in any space on the card), we may compare several ways of scoring noticed in the text (p. 80):

Points		Text (1)[1]	Winch[2]	Smith[3]	Text (2)[4]
3	=	a	a	a	a
2	=	b, c, j	b, d	b, c	b, d, f
1	=	d, e	c, e	d, e, f, g, h, i, j, k, l	c, e, g, h, i, j, k, l
0	=	f, g, h, i, k, l	f, g, h, i, j, k, l	——	——

A rote method of learning by the line would be favored by Text (1) and Smith, for its misplacements would be more frequently made within the line; by the column, by Winch, for a similar reason. A visual reproduction would be favored by Text (2), since *f* is a proximate location; and vague reproduction by Smith and Text (2), since they offer no zero value for reproduced letters. In partial justification of the zero value it may be urged that over half of the consonants of the alphabet are on the card, and that mere guessing would raise the score of reproduction in over half of the guesses, especially when some of the consonants are known and the chance for correct guesses is consequently increased. If the letters are really reproduced, however, they should contribute to the score.

Perhaps the assignment of values should not be made until all the misplacements of a given reagent are tabulated and the various kinds of misplacement are compared with degrees of reproduction as revealed by an analysis of his mental processes; then the values could be assigned with reference to the degree of reproduction, which might be found to decrease with the frequency of the kinds of misplacement.

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[1] P. 80.
[2] Winch: Br. Jr. Psychol. 1: 129; also Whipple's Manual (1st ed.) p. 369.
[3] Smith: Mind. N. S. 4: 52. The writer's interpretation of the rather indefinite text is given here.
[4] P. 187.

Such a tabulation was made of the results from 20 experiments by each of ten reagents in Tests 13 and 17, and it was found that although there was considerable variation between the different reagents in the number of letters misplaced in 20 experiments (12-44, with an average of 15% of all reproduced letters in Test 13; 7-38, with an average of 29% of all reproduced letters in Test 17), within each test large individual variation in the kind of misplacing involved a few kinds only (in Test 13, misplacings *c* and *d;* in Test 17, *b, d,* and *f*). If frequency as found in the aggregate results would not call for a division of these particular kinds of misplacing into different classes for evaluation, a system of evaluations upon the basis of aggregate results might be available for general application. This condition is fulfilled, as may be seen from the following tables, but it necessitates a separate system of evaluations for each of the two tests.

All of the misplacings of all of the reagents in each test were tabulated and calculated with the following aggregate results (reduced to the average number of letters so placed in one experiment):

Test 13				Test 17			
j	c	b	a	j	c	b	a
.01	.215	.42	6.97	.015	.065	.285	2.245
k	g	f	d	k	g	f	d
.015	.085	.11	.26	.020	.080	.160	.200
l	i	h	e	l	i	h	e
.01	.025	.03	.035	.000	.045	.015	.045

But these amounts show the actual distribution of misplacings; if we assume that a misplacement which occurs more frequently should be penalized less in the score measuring reproduction than one which occurs less frequently (introspections are not full enough to indicate clearly whether it should), our system of arbitrary values could not be taken from the distributions shown above for the reason that the chance of making some misplacings is much greater than that of making others; *e.g.*, in chance guessing the misplacement *f* would occur 24 times to *l* 4 times. We should need this distribution as modified by the relative chances of the misplacings.

The Ratio of Recorded to Chance Misplacings would seem to meet this need. If position *a* is moved systematically over the card, occupying in turn every one of the 12 spaces, there would aggregate 132 possible misplacings distributed over the lettered relative positions as follows: 24, f; 18, b; 16, d, g; 12, c, h; 8, e, i, k; 6, j; 4, l. According to these chance values of the positions the 1.27 misplacings (per experiment) of Test 13, and the 0.93 misplacings per experiment of Test 17, could be distributed; position *d*, in Test 13 would then have the value of .153 instead of .26, the ratio of its actual occurrence to chance occurrence being 1.70. These ratios calculated for all the relative positions are presented in the following table:

Ratio of Recorded to Chance Misplacing.

Test 13				Test 17			
j	c	b	a	j	c	b	a
0.17	1.87	2.44		.35	.77	2.24	
k	g	f	d	k	g	f	d
.20	.56	.48	1.70	.35	.71	.95	1.77
l	i	h	e	l	i	h	e
.27	.33	.26	.46	0.00	.80	.18	.80

But it might be objected that we do not still have a measure of the relative frequency of the respective misplacings, since owing to the reagent's direction of his attention to one portion of the card rather than to another, the letters which in reproduction were misplaced may not have been distributed evenly over the 12 positions. Calculation sustains the objection so far as it suspects irregular distribution over the positions: The range in Test 13 is 13 (in the 1st position) to 33 (in the 7th position); in Test 17, 7 (positions 9 and 11) to 41 (position 4). When the actual chances for the respective misplacings are calculated, however, the results showing relative frequency of misplacings are substantially the same as in the tables above:

Ratio of Recorded to "Actual" chance misplacing.

Test 13				Test 17			
j	c	b	a	j	c	b	a
.20	1.87	2.33		.30	.77	2.39	
k	g	f	d	k	g	f	d
.22	.53	.44	1.67	.33	.69	.96	1.71
l	i	h	e	l	i	h	e
.32	.35	.27	.49	.0	.86	.21	.86

And if instead of pooling the results of 20 experiments by each of a dozen reagents we use the 450 experiments (like Test 17) by a single reagent (Mn.), in which the habits of attention may be expected to be more uniform and consequently more disturbing to our calculation on the basis of "regular" chance, the range in irregular distribution being from 4 (position 10) to 47 (position 4), and the number of reproduced letters misplaced being 242 (5%), we get the following remarkable approximation to the ratios with "regular" chance distribution:

Ratio of Recorded to

"Regular" Chance Misplacing				"Actual" Chance Misplacing			
j	c	b	a	j	c	b	a
.28	.41	3.22		.26	.41	3.32	
k	g	f	d	k	g	f	d
.55	.62	.92	1.18	.52	.61	.96	1.19
l	i	h	e	l	i	h	e
.27	.34	.27	.41	.26	.34	.28	.41

There is little doubt therefore that these tables furnish us with fairly reliable relative frequencies of the respective misplacings in these two tests. Upon the assumptions that the more frequent misplacing should be penalized less in the score, that three points shall be the value of a correctly placed letter, that in the interest of facility fractional values shall be avoided, and that great injustice is not likely to result in striking an approximate balance between over-evaluation and under-evaluation of respective misplacings, it would seem that the following values might be recommended :

Test 13. (Exposure 10 sec.)	Test 17. (Exposure 1/10 sec.)
3 = a	3 = a
2 = b, c, d,	2 = b, f, d,
1 = all others.	1 = all others.

The arbitrariness of forcing this qualitative difference in reproduction into a quantitative difference, has already been remarked. The *g* or *i* misplacings are only by courtesy to the strenuous statistician to be regarded as possessing one-half the reproductive value of misplacings *b* or *d*, and one-third the reproductive value of a correctly reproduced letter. Disregarded also is the partiality to visual memory: letters retained in vivid visual imagery keep their relative positions; letters reproduced from equally vivid auditory or kinaesthetic imagery may be free from either temporal or spatial order.

The values listed under Test 17 are those employed in our Text (2) method of scoring. It will be remembered that exposure of the card was about a tenth of a second; it is for this reason that *f* is a proximate position.

Upon re-scoring Tests 13, and 17, the average scores were found to range in points from 15.5 to 27.3, and from 4.1 to 9.1, respectively, and to increase only 0.36, and 0.61 points, respectively. Our Test (1) method was unsatisfactory, therefore, principally because it is an arbitrary method, and, like many mental test methods of measurement, confuses process and product. Its difference from other methods of scoring, equally arbitrary, has no bearing on our treatment of results, which, the reader has noted, is principally qualitative.

APPENDIX D

Influence of Subliminal Differences upon Judgment in Stimulus Comparison (Discrimination) (See Text, p. 185)

In experiments on Sensible discrimination in which the Method of Constant Changes, Right and Wrong Cases, is employed, it is commonly observed that, if the steps between stimulus-differences are small enough, R Cases (correct judgments on "greater" or "less") fall off regularly with the decrease in stimulus-difference even when these steps fall below the difference which is conventionally designated as the "Least Noticeable Difference." (50% R Cases. *vid.* Külpe: Outlines of Psychology, p. 69; or Titchener: A Text-book of Psychology, p. 213). This influence of "subliminal" differences upon judgment in stimulus comparison may be illustrated from our own data, if we aggregate the judgments of all reagents upon each of the intervals (stimulus-differences) in the respective tests and practices in Sensible Discrimination.

If we call the interval between the variable of least intensity and the norm the first, and the interval between the variable of greatest intensity and the norm the last (7th or 9th), we get the following table of R Cases, in per cent:

Interval	a	b	c	d
1	77	92	85	78
2	67	65	57	70
3	49	50	31	59
4	39	31	23	38
5 = Norm				
6	59	49	41	41
7	79	55	53	62
8		76	74	65
9		84	84	75

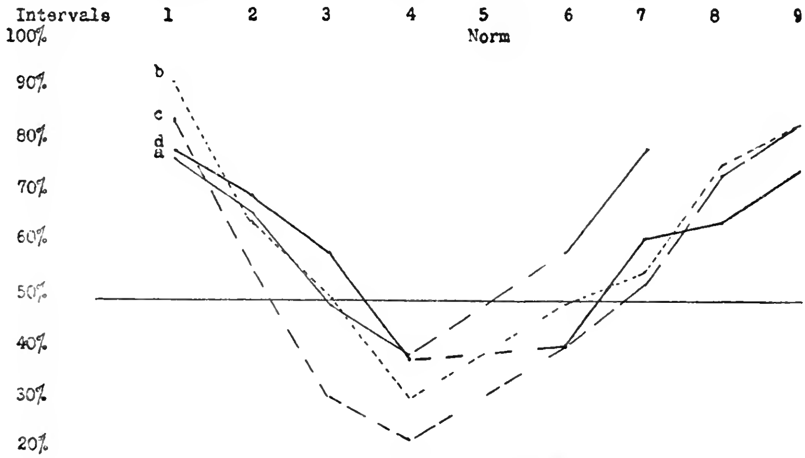
a = Discrimination of Brightness (180 judgments on each interval, 14 reagents) 1904-5. (Text, pp. 42ff.)

b = Discrimination of Sound with Sound Pendulum (160 judgments on each interval, 16 reagents) 1910-1911. (Text, pp. 134ff.)

c = Discrimination of Sound with Sound Pendulum (120 judgments on each interval, 12 reagents) 1911-1912. (Text, pp. 206ff).

d = Discrimination of Sound with Fall Phonometer (96 judgments on each interval(2 reagents) 1911-1912. (Text, 188ff).

The facts of the table are more apparent in the curves drawn from it:



The "Least Noticeable Difference" is 50% R Cases.

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(For the Name Register consult the Bibliography).

BIOGRAPHY

John Edgar Coover was born on a prairie farm near Remington, Indiana, March 16, 1872. In infancy he moved with his parents to their early home in Cumberland County, Pennsylvania, where he started to a village school in the winter of 1877-1878. In the Spring of 1878 his family moved to a farm in central Kansas, near Dorrance, where he attended a country school for about four years. Another removal to a still newer neighborhood, in the same county, resulted in poor school advantages for about six years. In the Autumn of 1890 he went to school at McPherson College (sectarian, German Baptist or Brethren) where he finished his study of the common branches and learned short-hand and typewriting. In the Spring of the next year he entered an office on the Union Pacific Railway where during a little over a year's station work he learned telegraphy.

In the Spring of 1892 he left home for Colorado (Denver) where he revived an early purpose to fit himself for teaching school. After considerable effort during a time while he worked as journeyman printer, and publisher of a country newspaper, he was enabled to enter the State Normal School of Colorado (Greeley) in 1893-1894, from which he was graduated in 1898. After serving as principal of schools in Como, Colorado, for one year, he entered Stanford University (California) (Autumn of 1899), where in January, 1904, he received the A.B. degree in Philosophy; and in May, 1905, the M.A. degree in Psychology to which department he presented a thesis on "Formal Discipline from the standpoint of experimental psychology" (from which a report was published, in collaboration with Professor Frank Angell, in the American Jr. Psychol., 1907, 18:328-340, under the title "General Practice effect of special exercise)."

After occupying the principalship of the Tuolumne County High School (Sonora, California) for two years, and of the Dixon Union High School (Dixon, California) for three years, he returned to Stanford University, became assistant in the Department of Psychology, and pursued research for two years more, leading to the Ph.D. degree.

Secondary and higher education had been pursued for 12 years, during which time expenses were met by earnings from short-hand and typewriting, printing, an assistant librarianship, telegraph operating, and teaching.

The present research occupied four school-years; during three and one-half it was almost wholly experimental.